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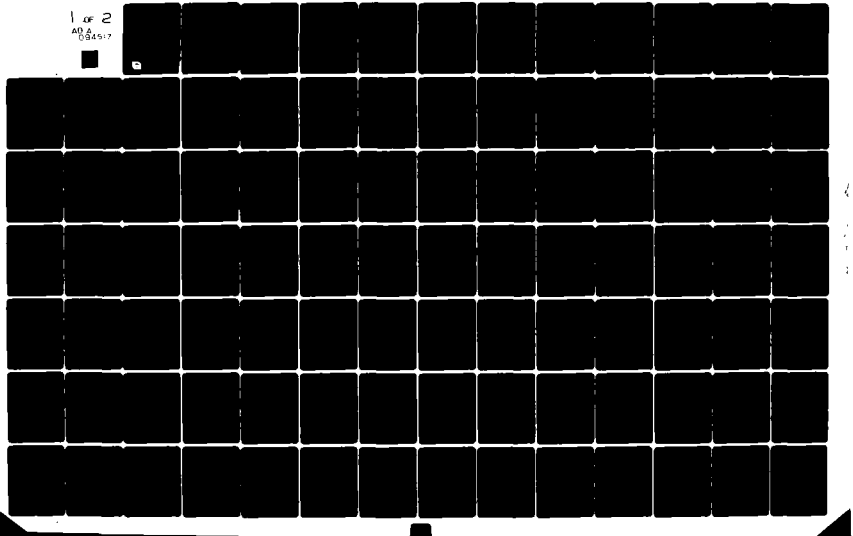

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DEVELOPMENT OF CIVIL DEFENSE DAMAGE ASSESSMENT PROGRAMS

Leo A. Schmidt

November 1980

Prepared for
Federal Emergency Management Agency

INSTITUTE FOR DEFENSE ANALYSES
PROGRAM ANALYSIS DIVISION

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This study documents efforts leading towards the development of a national damage assessment system to analyze damage resulting from a nuclear attack. It describes conversion of a number of programs from the IDA computer to that currently used at the FEMA Olney Computer Center. It documents computer programs developed for road network data base management and for nationwide fallout dose calculations. A narrative description of study activities and conclusions concerning requirements for damage assessment systems are presented.

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DEVELOPMENT OF CIVIL DEFENSE DAMAGE ASSESSMENT PROGRAMS

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November 1980

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PROGRAM ANALYSIS DIVISION
400 Army-Navy Drive, Arlington, Virginia 22202

Contract DCPA01-77-C-0215

Work Unit 4114G

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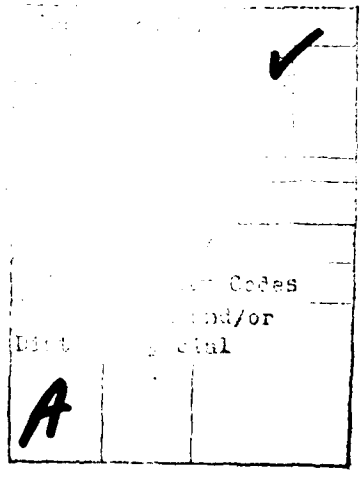

ABSTRACT

This study documents efforts leading towards the development of a national damage assessment system to analyze damage resulting from a nuclear attack. It describes conversion of a number of programs from the IDA computer to that currently used at the FEMA Olney Computer Center. It documents computer programs developed for road network data base management and for nationwide fallout dose calculations. A narrative description of study activities and conclusions concerning requirements for damage assessment systems are presented.

SUMMARY

This is the final report of work performed by the Institute for Defense Analyses for the Federal Emergency Management Agency on Contract DCPA01-77C-0215. It describes efforts in the conversion of damage assessment models previously developed at IDA for use in the DCPA computer facility, and the extension of these models for an enhanced damage assessment capability. An additional effort--an analysis of existing civil resource data bases--is described in a separate report [Ref. 1].

The models were developed at IDA to run in a batch environment on a Control Data Corporation computer and were written in FORTRAN language. They were converted to run in an interactive environment on a Sperry Univac computer. Although the changes in coding due to syntax differences were relatively minor, the changes necessary to take advantage of the interactive environment were found to be rather extensive. One program, ADAGIO, required extensive data packing to fit the memory limitations of the CDC equipment. Due to the differences in memory word size between the two machines, an extensive rearrangement of the packing structure was necessary.

As a result of this study effort, a number of general principles of good data processing were judged to be of particular applicability to damage assessment systems. These principles are:

Flexibility--the capability of the code of a damage assessment system to be modified to meet the needs of a particular study;

Accessibility--familarity of the programmers at the damage assessment facility with the damage assessment code;

Understandability--documentation of the essential algorithms in simple technical writing language, not computer jargon;

Data Documentation--adequate documentation of the sources of data files;

Ease of Model Use--the ability to explore parametric variations without excessive input file preparation or use of computer time;

Usable Output--the ability to control the types and extent of output to meet particular needs;

Verifiability--(in summary of the above features) the ability to ensure that valid implementation of proper algorithms is used to solve the proper problem with the correct data.

In order to study the amounts of time required to complete an evacuation, the development of a road network data base was undertaken. The data base is described and a set of data base maintenance programs are documented.

A stochastic fallout model developed by Carl Miller was converted to the Univac machine and extended to allow extensive testing. This fallout assessment program is documented. Fallout patterns presented illustrate the large variations in fallout deposition patterns which the model produces due to random features.

A new fallout calculating program was developed and is documented which uses the WSEG-10 fallout model, the "cluster" fallout model [Ref. 7], and a combination of the two. A number of alternative procedures are available in the model for handling map variations and wind conditions.

A new fallout calculation procedure was developed and is documented. This procedure considers one weapon at a time and deposits all the fallout from this weapon upon mesh points of an equal area grid covering the United States. Because of the inverted nature of the calculations (compared to the usual procedures), very substantial reductions in computer running time have been found when using this program to evaluate the effects of a nationwide attack.

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Chapter I

INTRODUCTION

This is the final report in response to Federal Emergency Management Agency Contract No. DCPA01-77C-0215, initiated 3/13/77.

The original statement of work was to begin development of a national damage assessment model based on various submodels previously developed for various analytic purposes.

More specifically the contract stated:

> B. Specific Work and Services - The work undertaken shall include but not be limited to the following:
>
> (1) Using existing damage assessment programs, perform sensitivity analyses to determine which programs can be most efficiently adapted to the Defense Civil Preparedness Agency's new Sperry Univac 1100 computer.
>
> (2) Undertake such redesign and reprogramming as is necessary to provide the Government with an efficient national damage assessment model to give relatively compatible answers with the Test and Evaluation of Local Operating Systems (TELOS) model at fairly low aggregations, at least down to the State level.

On 4/19/78 the contract was amended to proceed towards the goal of a final damage assessment capability model by providing the following additional efforts:

> (1) The initial capability envisioned would have only a single method of blast damage and fallout damage assessment. The addition of several alternative types of models of damage assessment along with a selection procedure among these models is now proposed.
>
> (2) A more extended initial input-output capability is proposed which will better take advantage of the

Sperry Univac 1100 computer capabilities. This will be built using the interactive version of the ADAGIO computer program as a starting point.

(3) Efforts will be initiated to develop a dynamic damage assessment capability. Preliminary models will be developed to describe the vulnerability of the population during various phases of a strategic crisis, according to postulated scenarios of the steps in the crisis.

(4) The data base effort will be expanded to include a preliminary description of items, primarily the highway and railway networks, which will be needed in the development of the dynamic vulnerability models.

This report describes the work accomplished on these efforts. On 19 March 1979 the contract was further amended to "...perform a sensitivity analysis and evaluation of the adequacy of existing civil resources data bases...." The results of this effort are described in IDA Paper P-1483 [Ref. 1].

It was found desirable to separate the damage assessment activities into a number of specific program areas. This report will generally follow this program area division as a natural means of catagorization.

Chapter II is a narrative description of the project activities; it describes the objectives in each program area and the activities pursued to achieve these objectives. Chapter III contains general and specific conclusions gleaned from the efforts on this study. In particular it contains a discussion of the means by which damage assessment models may be effectively utilized by FEMA and the implications for future large model development. Chapter III concludes the general discussion of damage assessment models and their utility. Chapters IV through VIII are more detailed and are presented for the reader who wishes to become more familiar with model operation and documentation; general familiarity with computer programming is assumed.

Chapter IV describes the specific conventions used in this series of programs as adapted to the Sperry Univac computer and general methods of operations of these programs. Chapters V through VIII contain computer program documentation in specific program areas and examples of program use. Since a number of program areas contain programs developed earlier and documented in IDA papers, those descriptions will not be repeated here. The earlier documentation is as follows:

- An overall documentation of IDA programs is given in [Ref. 4].
- Program Area P2., ADAGIO, is described in [Ref. 5].
- Area P4., ALLEGRO, is described in [Ref. 6].
- P6., RUBATO, is described in [Ref. 7].
- P7., FIRE PROGRAMS, is described in [Refs. 3, 8].
- P8., EDITING PROGRAMS, is described in [Ref. 4].

Chapter II

NARRATIVE OF PROJECT ACTIVITIES

During the course of this study, extensive use was made of the Sperry Univac 1100 computer with a variety of models and programs. A formal program documentation does not adequately describe many of the study's activities and the rationale underlying many of the choices; therefore this narrative description is presented in a less formal format to facilitate a clearer understanding of the lessons learned in this study.

The initial effort in this study was to transmit those computer programs and subroutines described in [Ref. 4] which appeared to have potential usefulness to the FEMA computer facility at Olney, Maryland, and to enter these items into this computer system. All these programs were operating on a Control Data 6400 computer and written in CDC FORTRAN, Version 3.0. The first effort was to compile this with the Sperry Univac 1100 computer in ASCII FORTRAN and to make those changes necessary so that all syntax was correct. With two exceptions, the syntax of the two languages was sufficiently similar; only minor difficulty was experienced in conversion. Both exceptions had to do with character constants. The acceptable delimiter of a character constant CDC FORTRAN is a star, and in ASCII FORTRAN, an apostrophe. All the WRITE statements with these delimeters (which was the majority of the WRITE statements) had to be changed. In Univac ASCII FORTRAN, the CHARACTER declaration statement must be used to define the length of a character string,

where in CDC FORTRAN there is no such statement. Fortunately the text editing capability of the Univac system allowed these changes to be readily made.

Following the initial conversion two problems remained--(1) adapting the program to run effectively in the new environment, and (2) ensuring that the program was still correct. The first problem arose because the CDC-oriented programs were designed to run in a strict batch environment where data storage was either on IBM cards or magnetic tapes, and where printer output was directly available. On the Univac machine, either interactive or batch environments were available and files could be readily stored on mass storage devices; output was often through a terminal with limited data transmission rates. Thus, for effective use, the computational strategy for implementing a group of algorithms often changed and the input/output structure revised.

As with any program conversion, it is necessary to ensure that program algorithms are not inadvertantly changed. Since this is an appreciable effort, it was decided to divide the available routines into program areas and consider each program area separately.

A. P2. ADAGIO

The first program area chosen was P2., program ADAGIO, which studies evacuation requirements. ADAGIO was chosen since an interactive version of this program was developed on the Control Data KRONOS time sharing system [Ref. 5]. The first objective was to reproduce the results of the KRONOS version, in particular to reproduce the illustrative calculations in [Ref. 5]. This was achieved, but with some difficulty; owing to memory constraints, the program as implemented on the Control Data machine required extensive

packing of array variables into single words. The smaller word size of the Sperry Univac computer required redoing the entire packing structure. The Control Data program was written with transportability in mind. Fortunately the great majority of the packing and unpacking operations were concentrated in two subroutines, PACK and UNPACK, which utilized features unique to the Control Data FORTRAN and which were rewritten utilizing unique Univac ASCII FORTRAN features, Nevertheless, there were problems in introducing new packed variables, needed because of the smaller word size on the Univac machine, and ensuring that these variables were properly defined and available in those parts of the code which utilized them.

The original interactive ADAGIO was designed to be as flexible as possible in terminal operation. To achieve this, the overall structure was divided into nine separately executable elements acting upon five separate files. This structure is preserved in the Univac version. It is much more convenient, in both versions, to have this independent file and program structure, not only for flexibility but also to allow ready exploration of parameter variations and for comparing one type of result with another. As will be seen, some shorter programs were better constructed as a single element.

An empirical rule for damage assessment programs seems to be that no single program should be more than 2000 to 3000 lines long. Dividing programs into short elements does introduce operating complexity, however, this additional complexity is usually more apparent than real since, with a single long program, the necessary control must be obtained through manipulation of a variety of input parameters which often place even greater demands on the user to obtain the type of calculation desired.

B. P4. ALLEGRO

In the next program area, P4., the program ALLEGRO was converted [Ref. 3]. This program is a rapid running attack generator and blast damage assessor. It assesses urban target area vulnerabilities through the use of the square root damage law. Targets can be defended by area or terminal ballistic missile defense. This type of calculation enables a very rapid nationwide attack optimization and damage assessment--in the order of a few minutes. In the original version, the program could optimize attacks against either population or economic value. The economic data, however, dated back to 1963; due to their vintage, these economic data were not transferred and only the attack generation against population was implemented. The implementation of this program was direct, with no serious problems encountered.

One application of this program was to assess the effects of an attack optimized against relocated population at various levels of evacuation and sheltering [Ref. 12]. The ALLEGRO program was modified to correct input populations for evacuation based on nationwide population packing factors obtained from FEMA. Here the ALLEGRO outputs contributed to a manual optimization of the attack between urban and rural population.

C. P5. ROAD NETWORK PROGRAMS

The next set of programs developed, program area P5., were new programs written as maintenance programs for a nationwide road network data base. This data base includes all interstate highways, all major federal and state numbered highways, and secondary roads to the point where at least one road junction is located in each county. This data base is being developed to assist in the analysis of population vulnerability during a strategic evacuation by

allowing for calculations given the rate of evacuation traffic flow. It consists of a set of nodes representing population centers or major road junctions outside of population centers. Associated with each node is the county code, a counter giving the number of the node in the county, a name and a node location. These nodes are connected by links which represent roads. Associated with each link are identifiers of the two end nodes, the type of road (interstate highway, US federally funded highway, or state highway), the route number, and a road quality indicator.

To simplify processing, the data base was developed one state at a time. The locations of roads and nodes were taken from standard highway road maps. One requirement imposed was that there be at least one node in each county. One node (in each county) was selected as a principal node, additional nodes (in each county) were selected as needed, and finally the links joining nodes were drawn. As the nodes and links were selected, they were marked on the source map and the appropriate entrees made on data forms. The principal source of trouble in this procedure was obtaining geographic coordinates for the nodes. Since there was a separate road map for each state and the projections and scales of these maps were unknown (the scales could be roughly obtained from distance scale on the map), it was deemed impractical to obtain locations from map measurements which both preserved local directions and directions between nodes in adjacent states. The only known source of geographic locations at the level of detail needed was the 1970 Census Bureau MEDLIST file which had processed the data into urban areas, towns and rural population by county. This file was used to give an initial location to the principle node in each county. Where MEDLIST had a town or city in the county, and its dimensions were not too large,

it was used to give the principal node location. Otherwise the nearest available town or estimates of the location of the rural population centroid was used. Other nodes in a county were located in terms of their displacement from the central node.

Several programs were developed to assist in analysis of these data. Program SELECT was developed to take nodes and links for a particular state from the network data file and place them in two individual state files in the proper format. Program LINKLOC was developed to add geographic coordinates to each end of the links in the link file by using the node descriptors with each link to find the geographic coordinates of the two nodes at the ends of the link and adding them to the link file.

The next problem encountered was that of checking the accuracy of the data; two aids to this procedure were developed. Program NODROD was written which lists all the links connected to a certain node. Using this output, all the nodes can be located on a road map, and the links associated with each node can be readily compared to those on the map. This procedure was an effective means of checking for gross errors such as links missing or incorrect nodes associated with a link.

A plotting program was developed to plot the locations of nodes and links. This program used a Hewlett Packard 11"x14" plotter driven by a Hewlett Packard 9830 calculator which could also be used as a terminal connected with the Univac 1100. (The FEMA computer facility has a large flat bed plotter, but this procedure was adapted to give rapid turnaround time.) The operating procedure was to use a Univac program TRSBOTH to generate a data file in the format of the BASIC language, which was then transmitted to the Hewlett Packard calculator. The calculator then executed

a BASIC program which drove the plotter. The procedure was reasonably efficient, although sometimes frustrating to the operator who had to constantly remember whether he was using the Univac computer, the H.P. calculator, the plotter, or some combination of them; and which language he was using--Univac FORTRAN, Univac control, H.P. BASIC, or H.P. control.

It was found that node locations were generally accurate to several miles, although occasional gross errors occurred either due to MEDLIST data errors or to errors in measuring or transcribing. While a "few miles" error would be acceptable for the purposes for which the data were intended, it unfortunately often made plotted maps appear distorted, especially when a straight road would connect several nodes in a row where errors in the direction transverse to the road are very noticeable. To obtain better maps, corrections were made to the node locations by amounts which would preserve the local directions between adjacent nodes. When the plotting was repeated, much better maps were obtained, although occasionally a second set of location corrections was needed to obtain consistent plots.

In a Stanford Research Institute study of the feasibility of the evacuation of New York City, a set of 15 automotive evacuation routes in New York State were selected. This selection was done on the basis of a survey of available roads and in consultation with local officials. As a test of usefulness, the data base road network for New York State was compared to the set of SRI selected routes. For the most part, the road network did contain the routes selected by SRI. Use of the road network alone as a selection basis would have given a set of evacuation routes rather close to those obtained by SRI.

The major difference between the SRI routes and the data base were in the roads just upstate from New York City.

The location of New York City at the southern-most tip of the state, the constraint that all routes had to be in New York State (or, in a few cases, just over the border), and the mountainous topography of the section northwest of New York City, made this area the main bottleneck for evacuation. In an attempt to alleviate the problem, SRI chose a number of secondary roads as part of the evacuation routes. The feasibility of these routes would not have been clear just from perusing road maps; it required local knowledge. This suggests that other urban areas might have available similar additional secondary roads to support additional traffic flow, but that local resources are needed to locate such routes.

A final observation to be made concerning the development of the road network is that, in different sections of the country, the road networks look much different. The East, the Midwest and the West all have characteristic features to their networks, and subregions within each of these can be distinguished which themselves have recognizably different features.

D. P6. RUBATO

In the next program area, program RUBATO was converted to the Univac 1100 syntax, made operational, and tested. This program computes distributions of fallout doses on a set of nationwide monitor points through a Monte Carlo selection of sample winds from climatological wind distributions and evaluation of fallout doses for each sample wind at each monitor point. The conversion of this program was quite direct. One problem, however, presented difficulties for testing--the random number generators for the CDC and Univac machines generated different strings of psuedo-random numbers even with the same seed used to start the string

of numbers. Thus it was not possible to get exact agreement between the two machines, but only statistical agreement.[1] Nevertheless, the program implementation appears to be the same on both machines.

At the time of RUBATO implementation on the Univac machine, it was necessary to perform fallout calculations for a specific wind. Since the RUBATO program had both the original WSEG-10 fallout model and the cluster version of the WSEG-10 fallout model implemented, it could be used for deterministic calculations by simply choosing a sample size of one. The results were not satisfactory because, in the original stochastic calculations, it was felt adequate to use the wind occurring at the nearest wind grid point. For calculations with a single wind, however, drastic changes in the wind would suddenly appear in going from one grid square to another. This would give strange appearing dose patterns at places. An option was introduced into the RUBATO program to allow linear interpolation between wind points.

Since the calculations were presumably for a single wind, it was natural to want a real wind on a single day rather than some sample drawn from climatological data, either randomly or by some arbitrary rule. Accordingly, the program was again modified to accept real wind data on a grid. Programs were written to accept data in the format of winds supplied from Global Weather Central. A set of 12 "most probable winds" (a set of real winds from actual days developed by R. Mason of the Command and Control Technical Center) were used as input wind data. The program to produce

[1]Of course the random numbers from one machine could have been saved and used to simulate a random number generator on the other machine, but then the program would have to be operable on both machines. It was not felt necessary to reinstate the program on the CDC 6400.

the wind grid data would accept either raw wind data at five different pressure levels, or processed effective fallout winds. In the prior case, the data had to be averaged through all wind levels to obtain effective fallout winds. The original RUBATO program used a set of some 3000 monitor points which were the centers of county population. It also was deemed desired to be able to perform fallout calculations for a 10 minute spacing grid covering the United States (which was developed by FEMA), containing some 30,000 monitor points. A modification was introduced which allowed either type of input.

The original RUBATO program associated winds with the wind at the weapon location. If the wind streamlines are significantly curved (as is often the case), then the computed fallout patterns are significantly different than those which would have really occurred, since fallout follows the wind streamlines. Accordingly, subroutine CURVW was developed which allowed integrating along the wind streamlines to obtain downwind and crosswind distances to use in the fallout calculation model. Much more realistic appearing patterns were obtained using this new routine.

At this point, the RUBATO program combined several features of the original research program and the production program to compute fallout on a grid. The program had expanded well beyond the original research program without adequate regrouping of variables and routines or documentation. As a result the program became successively more unwieldly to modify and use, or to understand. It was felt that a significant effort was needed to clean up the program, which eventually led to the GRDFAL program in program area P11.

E. P7. FIRE PROGRAMS

The next set of programs addressed were the urban FIRE PROGRAMS, program area P7. [Ref. 8, 3]. The programs were named FIRETST, POPPOP and FIRESM. Efforts were restricted to conversion of program syntax and checking results against CDC 6400 runs. Since the last two programs were Monte Carlo simulations, the same type of checking problems were encountered as those encountered for program RUBATO. No effort was made to modify the programs since it was felt that substantial additions would be desirable before they were extensively used in urban mass fire damage assessment.

F. P8. EDITING

A set of data base management programs was developed in an IDA contract with DCPA (documented in Ref. 4). These programs combined population, economic and geographic data into files appropriate for input to the ADAGIO and ALLEGRO programs. The programs were developed for use on the Control Data 6400 in a batch environment. Many of the features of these programs were unique to the particular nature of the data bases involved, but many others could be more readily handled by system features of the Univac system. Accordingly, this group of programs was placed on the Univac system in program area P8., but no conversion efforts were made until specific needs occurred.

Another group of programs provided a plotting capability for the 6400 computer. These programs implemented a set of data averaging procedures and a multipage plotting capability. Those programs were also placed on the Univac system in program area P8., but were not converted until a specific use was foreseen.

G. ADDITIONAL PROGRAMS

This completes the list of IDA CDC programs converted and made operable on the Univac system. Several programs are described in [Ref. 4] which were not put into specific program areas. The programs are as follows: (1) The program ANDANTE was converted by J. Backman of the FEMA Olney Computer Center and used for a number of production runs; there was no need to repeat this effort. (2) A version of the programs AIP/ANCET was implemented at the FEMA Computer Center; since the basic algorithms were the same in the IDA and the FEMA versions, there was no need to convert. (3) The program MARATHON was developed to study optimized attacks against optimized mixtures of blast shelter and anti-ballistic missile defense [Ref. 11]; since there seemed to be no immediate need to analyze such defense mixes, this program was not converted. (4) The program GEM/PADECON was developed to study post-attack economic recovery [Ref. 6]. This program is the result of an extensive economic modeling effort; the model includes demand predictions, supply calculations, production functions, capital secretion, inventory and bottleneck calculations. A large economic data base is needed to run this model. An appreciable effort would be needed for program conversion and a major effort would be required to understand and update the data base (which is at least ten years old) and the original compilers of the data base are not available. Therefore, while it is felt that this approach to modeling economic post-attack recovery is valuable, the resources needed to update the data base are beyond those available. (The economic data base of [Ref. 1] is of a different type. It is concerned with individual facility data for damage assessment, while GEM uses nationwide averaged data of many different types.) (5) A number of small special purpose programs were listed in [Ref. 4]. If the need arises to use such programs, it

would be as efficient to rewrite the programs as to attempt program conversion.

H. P9. MILLER-S

The MILLER-S fallout model is a unique approach to fallout prediction which assumes that a number of features of fallout deposition result from uncontrollable variations of nuclear weapon explosions, and which calculates fallout patterns for a weapon by randomly selecting values from probability distributions [Ref. 9]. This model was implemented on the DCPA Control Data 3600 computer in an experimental version. In the next program area, P9., this model was converted to the Univac 1100 computer. Reference 9 contains results of a sample run, but since the model used strings of random numbers, the CDC 3600 results could only be reproduced in a stochastic fashion, as with the RUBATO program. In this case, confidence in the program results could only be obtained by carefully checking the coding against the model definition in [Ref. 9]. In the course of this process, several coding errors in the original implementation were discovered and corrected.

The original program was designed to accept a limited set of monitor points as input and calculate fallout doses for these points. In order to make the model suitable for more conventional damage assessment calculations, a rather extensive restructuring of the basic code was performed. The calculations which varied from monitor point to monitor point were isolated, and subroutines were developed which separated the common calculations for all monitor points from those varying with each monitor point. The flow of calculation was restructured to minimize the number of calculations in the latter category. New input and output routines, as well as a capability to plot the output doses, were written.

Reference 10 contains several additional modifications to the code which were also incorporated in the model. The model was extended to allow computation of biological dose in addition to the H+1 hour dose rate, and a method of controlling the total radioactivity deposited, the "k-factor." Testing the model under conditions of low wind shear gave physically unrealistic upwind and crosswind fallout depositions. Changes were made to correct this.

The model was examined under a number of different wind conditions. A program was developed to obtain winds for use in the MILLER-S model from daily raw wind reports. These winds were used to illustrate types of patterns obtained under various types of wind conditions. In low shear/high wind conditions, patterns similar in general appearance to WSEG-10 patterns were obtained, but even in these conditions the pattern details were often dominated by the random appearance of local "hot spots."

The MILLER-S model requires the storage of about 250 variables for each weapon processed, which effectively limits the MILLER-S assessment to about one or two hundred weapons at a time. In order to obtain an efficient nationwide damage assessment program, a different method of procedure is required. The requirement gave rise to the program GUISTO, described in program area P12.

I. P11. GRDFAL

Program area P11. was developed with the intent to strip the RUBATO program of everything that was not needed for a calculation of fallout doses from a single wind. The resulting program for the single wind assessment, GRDFAL, is an almost complete rewrite of those portions of RUBATO saved. In addition, the number of options for assessment conditions were expanded. In particular and for completeness,

the option for calculating distances and angles on the assumption of a spherical earth were implemented, although this required considerably longer running time. The program has the options of computing fallout doses by using individual weapons with the WSEG-10 model, only using weapon clusters with the simplified cluster modification of the WSEG-10 model, or for a combination of clusters when the weapons are distant, and individual weapons when they are close.

J. P12. GUISTO

The final program area, P12., was begun as an experimental program looking towards a method of implementing a nationwide MILLER-S deposition model. The procedure was to deposit all fallout from each weapon at intersections on a grid. Since the grid was to cover the entire United States, a flat earth assumption was unacceptable; a grid tied to lines of constant latitude and longitude would exhibit biases due to the converging of the lines of constant longitude. Rather than attempt to correct for biases due to this converging, a grid where each grid square has an equal area was attempted. This led naturally to taking an equal area map projection, and the Albers equal area projection was selected. This usual projection has standard parallels at 29-1/2° and 45-1/2° when used for the United States (which was adopted here). This is a conical projection with straight lines for lines of constant longitude and circles for lines of constant latitude. The maximum scale error for the United States is 1-1/4 percent. Local directions are distorted by the cone angle, which covers 36° for the United States. However, by correcting local wind direction by the local cone angle, winds will blow in the projected plane in the correct direction.

The test program GUISTO was written using the WSEG-10 model as a test bed. For each weapon, ten mile steps (the

same spacing as on the Albers grid) were taken in the upwind and downwind directions until the hot line dose was small enough. At each of these downwind locations, ten mile steps were taken in the crosswind direction, again until doses were small enough. For each of these points, the fallout dose was computed and then distributed to the adjacent grid corners.

When the program was tested, it was found that a nationwide fallout calculation with this program took about 1/10 the time of a normal calculation, e.g., with the program GRDFAL. Upon reflection, two reasons for this surprising speed became apparent: (1) the normal screening operation, where at each monitor point each weapon must be tested to see if it contributes fallout doses, was not needed; and (2) full advantage could be taken of the separability of the WSEG-10 model into yield-sensitive, wind-sensitive, downwind distance-sensitive, and crosswind distance-sensitive components. The program GUISTO was then documented and made ready for production use. To take advantage of the program capabilities, a terminal plotting capability was developed to graphically exhibit fallout dose values under various conditions.

Chapter III

GENERAL CONCLUSIONS

Section A discusses some general conclusions concerning features of optimal damage assessment systems. Section B offers conclusions concerning the specific program areas studied.

A. DESIRABLE FEATURES OF DAMAGE ASSESSMENT SYSTEMS

In the course of this study, some conclusions were drawn concerning the desirable features of a computerized damage assessment capability[1]. These conclusions are really qualitative judgments and thus the presentation will attempt to include a rationale for such judgments, supported, where possible, with examples. Although many are simply good principles of data processing, those qualities judged to be of most interest to FEMA are presented.

1. Flexibility

It is not really feasible during the development of a damage assessment system to anticipate all the variations in assumptions which the system will have to handle. Each individual study which uses a damage assessment system will have its own requirements for population locations, sheltering assumptions, attack scenarios, data bases, methods

[1]The word capability is used here to represent the ability of a computer facility to perform damage assessment calculations on request. In so doing they may use a number of programs organized into a damage assessment system.

of treating statistical parameters, volume of calculations and time available to accomplish the calculations. Moreover, each study will generate its own requirements for the type and format of results to be generated. An optimal damage assessment capability would be able to adapt itself to individual study requirements rather than forcing the study to scale down its requirements to meet existing capabilities.

A corollary is that it is unprofitable for the developer of a damage assessment system to attempt to develop programs which will handle all options, and then hand it over to a user in expectation that, by simply changing input parameters, the programs could handle all possible contingencies. Examples where extensive flexibility was tested are the BRISK-FRISK system, originally developed at IDA and converted into a large, documented system at LAMDA Corporation; the ANCET program developed at Research Triangle Institute; the NEVUNS system, using ANCET as a central point, developed at IDA; and the final implementation of the DASH system by Systems Sciences, Inc. In each case, the operational flexibility inserted by the program developer was not used, once the program was handed to the user. What did happen was, rather than try to use the complex input structure, the system users would make modifications to the programs to fit the needs of individual studies. In fact it appears that, the more complex the input structure, the more difficult it is to effectively use the system.

2. Accessibility

A prime requirement of a damage assessment capability is the availability of programmers at the installation who understand the damage assessment systems to be used and who have the capability to modify these systems to fit specific situations. A damage assessment capability cannot be

purchased and stored in a magnetic tape file until needed; it requires continuous attention.

The introduction of modern computer systems with extensive file handling capability and interactive control of data processing implies that an optimal system should complete its calculations by states rather than in one large calculation. Thus, separate calculations might be made for population locations, sheltering availability, blast damage, fallout doses, etc., with the output of one sub-effort affording the input to the next. In this process, the required flexibility and control are provided by personnel at the computer facility who are familiar with the system and can readily modify it. An example of this is the TENOS system currently implemented at FEMA. A second example, responsive to somewhat different requirements, is the SIDAC system implemented by the Command and Control Technical Center of DCA. Here the basic methods of calculation are fixed by the requirement to use the vulnerability number procedure of the Defense Intelligence Agency. The required flexibility is achieved by separating input data bases into those elements needed and processed by SIDAC, and other elements of interest to the user not processed by SIDAC but merged with the output files after SIDAC processing; by having specific points in the program where the user can add to or substitute for the basic capability; and finally by having the people who developed and who maintain the system accessible for advice and assistance for specific studies.

3. Understandability

Another prime requirement of a damage assessment system is that it have no mysterious black boxes. Every portion of the system should be well enough understood so that a

judgment can be made as to whether a particular part is appropriate in a particular calculation, or can be changed if necessary.

It is a further requirement that the model implemented be described according to the normal procedures of technical report writing, free from computer jargon. The descriptive material must be understandable to someone unfamiliar with the system's computer language. If such descriptions are not in already published technical reports, then they should be prepared by someone familiar with the basic physics, and not just the computer implementation per se. Without an understanding of the physical and mathematical bases of a damage assessment system, no judgment concerning its acceptability is possible. The following three items also contribute to understandability.

a. Style

The program must be written with good programming style; this includes adequate numbers of comments in the program and a direct (not convoluted) writing of the lines of code. Certain types of programmers attempt to display their competence by writing codes that obfuscate the algorithms by such complexity that they are almost impossible to understand, rather than by writing code which is clear even to the casual reader. Several portions of damage assessment codes used by FEMA are written in such poor style that a major effort is required simply to understand what the code does, much less attempt modifications.

b. Modularity

A prime aid to understandability is a high degree of modularity. Programs should be divided into subroutines, and variables communicating between subroutines should be

grouped through the use of block commons. Moreover the modularizing should not be arbitrary, but should be based upon natural subdivisions of the program logic. It should be possible for a reader of the code to understand the workings of any particular subelement at a single reading.

c. Program Documentation

Good program documentation aids understandability. It is not true that the value of program documentation is directly proportional to its length. Excessively detailed documentation is often as unenlightening as poorly written code, and a combination of poorly written code and detailed documentation written without understanding is overwhelming. Good documentation should provide an overview of the system, a description of its parts, their interrelationships, and a description of the input required to use the system. If the code itself is clearly written, then the documentation limited to descriptions of the subprogram structure, input, and common variables should be adequate for someone reasonably familiar with the system to both operate and maintain it.

4. Data Documentation

A most often neglected feature of damage assessment calculations is adequate documentation of the preparation of input data files. Such documentation should include file format, definitions of file variables when such are not obvious, basic sources of the data, and processing of the basic sources to obtain the file. The documentation should be sufficiently complete so that someone could independently duplicate the file if necessary. Vol. III of [Ref. 4] is an example of file documentation for damage assessment data files which attempts to achieve file duplication.

Most often, the developer of a particular data file can informally describe the process to create the file and can recreate the file if necessary. However, this capability typically seems to decay exponentially with a time constant of about five months. Since it often takes considerably longer for inquiries concerning a data file to develop (either in response to the calculations of a particular study or for possible uses of the file in future studies), these inquiries often can only receive an inadequate answer. Some form of documentation for data files is necessary to alleviate this loss of capability. At least part of the documentation should be relatively formal and standardized for all those at a particular facility working with damage assessment calculations. A well designed system need not be onerous to use.

5. Ease of Model Use

A damage assessment system should be sufficiently easy to use so that an adequate number of parameter variations can be tried in a particular study. This implies that the preparation of input data is relatively simple and straightforward, and that the computer resources required for the calculations not be oppressive. Besides efficient algorithms, segmenting calculations into smaller size steps to eliminate unnecessary repetition of parts of calculations often aids in reducing the total amount of calculation necessary.

6. Usable Output

The output from a set of damage assessment calculations should be available at various levels of summarization and should present various types of information upon request. The output should not only present the final values' specific numbers, but also should assist in understanding why the

numbers had those specific values. Well designed formats, options for selecting type of presentations, and graphical presentations, where applicable, all should be available.

7. Verifiability

Several of the previous features can be combined into this final feature. It should be possible to ensure that the answers produced are in fact valid implementations of the proper algorithms to solve the proper problem with the correct data. This verifiability should be available at various levels of inquiry, from quite broad to most specific and detailed. Most often this question arises when the results of a particular study are compared to some other study and someone wants to know why the results are different. Each of the studies should be sufficiently verifiable so that this valid and proper question can be answered.

B. SPECIFIC CONCLUSIONS

This section presents conclusions related to specific program areas. These conclusions are based on data processing possibilities, and are not intended to be predictions of specific FEMA requirements.

1. ADAGIO

The ADAGIO program was originally a program to allocate people from risk areas to evacuation areas in a fashion so as to minimize average travel distances subject to a set of constraints. To this was added capabilities to adjust initial allocations based on these requirements and manage the resultant data files. The program is highly developed and no further development is necessary unless specific calculations not covered by current capabilities are required.

One possible future use of this program is in conjunction with the road network data base in determining evacuation routes and rates.

2. ALLERGO

This program is a rapid attack generator and damage assessment procedure operating on urban complexes. It can allocate on the basis of population value or economic value. The current economic data base is quite old. New economic data bases should be constructed, possibly starting from data in the city-county data base. The program can readily operate with other kinds of values, for example, militarily significant targets. The possibility of adding such targets to a data base and extending the program might be considered.

This program determines the number of weapons to be allocated to a single urban area but does not generate specific weapon locations. The possibility of combining this program with another program which does weapon location within one area to do overall attack optimization should be considered.

3. Road Networks

The road network data base should be used as part of the development of a dynamic damage assessment system. Further development of the data base should wait until the dynamic damage assessment systems are further developed and any possible specific requirements of the data base become apparent. It is anticipated that portions of the data base maintenance programs will be used in a new model. Again changes should await further model development.

4. RUBATO

The RUBATO fallout risk assessment program currently has a number of modifications to allow fallout assessment with

specific wind patterns. At least one version of the original program should be created without these modifications. A possible extension of the program is to combine stochastic wind distributions with stochastic shelter distributions to obtain distributions of fallout fatalities.

5. Fire Programs

The fire programs currently available provide a good starting point for the development of a more complete fire spread model. This model would consider fire spread in and between tracts. For purposes of fire evaluation, tract boundaries should conform to natural firebreaks. However, for data gathering, other tract definitions (e.g. census tracts) may be needed. Depending upon the availability of data, the fire spread mechanisms in the current models may be found to be either too detailed or not sufficiently detailed. In developing such a model, a city should be used as a test bed to determine data availability. The models should be extended to consider blast damage in determining fire susceptibility and to include most fire effects in influencing fire spread.

6. MILLER-S

Currently available fallout models can be classified into three categories of use: (1) as a research tool--the DELFIC model; (2) for use in damage assessment systems--the WSEG-10 model; (3) for fallout patterns best reproducing actual fallout patterns--the MILLER-S model (owing to the random hot spots which are produced by this model). Further experience should be gained in the use of MILLER-S, and its possible use for nationwide damage calculations explored.

7. GRDFAL

This program was developed to obtain fallout doses in production calculations using the WSEG-10 model. Where details of the dose rate as a function of time are desired, this program should be used for fallout calculations.

8. GUISTO

This computer program can rapidly calculate fallout doses from winds on a specific day with the WSEG-10 model. It should be used for damage assessment system calculations when computer time is a significant consideration.

C. FURTHER COMMENT

The remainder of this report, Chapters IV through VIII, documents the program formats and specific program areas of damage assessment systems. It is presented in greater detail for the reader who is interested in model operation. A general familiarity with computer programming is assumed.

Chapter IV

STANDARDIZED PROGRAM FORMATS

In order to simplify the development and use of the series of programs in this study, a set of conventions has been adopted for naming the various elements of a program file; this set of conventions is described here. In this description the terminology of the Univac system will be used, but the operation details of the system will be suppressed as far as possible. To those familiar with the Univac operating system, the suppressed details will be obvious.

In the Univac system, a number of programs, subprograms, data files, etc can all be stored together as elements of a single file called a program file. In Univac usage, a file or element name can be defined by up to 12 characters. However, a more restricted usage is specified here. In this standard usage, a program file is denoted by the letter P followed by a number. The element name of a file is "P3" written as *P3.NAME.[1]

A computer program generally consists of a main program and several subprograms. In normal FORTRAN usage, the program and subprogram names are restricted to 6 or less alphanumeric

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[1]This format is acceptable to the Univac system. In the Univac system a qualifier, which is a string of up to 12 characters, is used to distinguish between two files with the same name. The qualifier may be associated with a run, in which case the above description is adequate. If a different qualifier is associated with a run, then a file element is described by LASH*P9.NAME. In this string of symbols, the asterisk and period are necessary in the Univac system.

and subprogram names are restricted to 6 or less alphanumeric characters.[1] The source codes are stored as elements in a program file as an element with the letter N as a prefix to the program or subprogram name. Thus the source code for the subroutine CALCN of the program COMPLX would be stored as an element called NCALCN, and the main program as the element NCOMPLX.

From original source code for each program or subprogram, the FORTRAN compiler produces a set of instructions in machine language. Since locations are given only relative to the start of the subprogram, the compiler output is called a "relocatable element." A separate process, mapping, links together the relocatable elements and produces a single linked code which can be executed. Since all addresses are now given relative to the start of the computer memory, this is called an "absolute element." The relocatable elements produced by compilation are named by adding the letter R as a prefix to the program or subprogram name. The absolute element produced by "mapping," which is an executable program, is denoted by a prefix S added to the program name. Thus the relocatable compiled subroutine CALCN would be stored as RCALCN, the relocatable main program as RCOMPLX, and the ready-to-run program with all subprograms linked as SCOMPLX.

In the Univac system a set of activities can be executed by adding a program element to the run stream of tasks yet to be performed by the operating system. To add the element XBUSY of the file LASH*P3.(here, P3. is the file name, the prefix LASH* is called a qualifier in Univac terminology and is used as a prefix for all files considered in this study), one would transmit to the computer the string @ADD LASH*P3.XBUSY. The mapping process is accomplished by elements named by adding the prefix V, thus the element VCOMPLX, in file P3., say, would accomplish the mapping process by transmitting @ADD LASH*P4. VCOMPLX. Unless a user wishes to change a program element, he

[1] In the Univac ASCII FORTRAN a main program name is not used. Nevertheless it is assumed here that each main program does have a name for 6 or less alphanumeric characters which is used to generate file names.

need not be concerned with any program elements initiated by the prefixes N, R, V or S.

In order to execute a program, typically a set of files (for input data, input control, etc.) must be associated with the program and execution initiated. This is accomplished here by adding elements to the run stream consisting of the program names with the prefix Q added. Thus to execute the program COMPLX, the string @ADD LASH*P4.QCOMPLX would be transmitted by the user. In some programs all input data are input at a terminal in response to prompting from the program. In most, however, a set of input parameters are stored in an element of a program file named INPPAR.

After a program execution, certain cleanup tasks such as saving temporary files or closing files are accomplished by adding to the run stream a set of instructions contained as an element called by the program name with the prefix P added. This addition is accomplished automatically by the executing program and need not concern the user unless he wishes to change the destination of the output data.

In certain applications it may be desirable to have a second version of a program with the same program and subprogram names (e.g. one version may have output of up to 120 characters per line, for listing on a printer, while another may allow only 70 characters for listing on a terminal); to allow for this, a second set of standard prefix letters have been defined as follows:

H replaces N
G replaces R
J replaces S
K replaces V
L replaces Q
A replaces P.

For use in a batch run environment (i.e. in a situation where a run proceeds independently of any terminal operation), certain other changes may be desired. The following set of standard

prefixes are defined:

E replaces N
F replaces R
M replaces S
D replaces V
B replaces Q
C replaces P.

Common blocks (collections of variables which communicate between subprograms) may appear in a number of subprograms. A Univac system program, called the Procedure Definition Processor, is available to assist in changing common block structure. This is done by changing variables in an element which is input to this processor, and placing in each subprogram using a common block an INCLUDE statement which ensures the common block will be included. The element which contains the input to the procedure is called INCOMM. The procedures defined for use in a subprogram by the INCLUDE statement are named by adding the prefix B to the common block name.

Chapter V

PROGRAM AREA P5., ROAD NETWORK DEVELOPMENT

A. INTRODUCTION

1. General Area Covered

This group of programs is designed to assist in the development of a data base representing those major roads in the United States that might be used in a national evacuation. The road network consists of a set of nodes (representing cities, towns, or road junctions) and links which are roads connecting the nodes. Since a county is a basic political unit in defining reception centers, it is a requirement of the network that each of the 3,100 counties in the United States contain at least one node. Other nodes are added as needed to describe major population centers or necessary road junctions to adequately represent the road system. A nationwide total of some 5,000 to 6,000 nodes is anticipated for the data base. The links are defined by two nodes and additionally described by interstate, federal, or state routes, route numbers, and a quality index as follows:

1 = More than four lane interstate quality
2 = Four lane interstate
3 = Four lane limited access
4 = Four lane unlimited access
5 = Major two lane highways
6 = Intermediate two lane highways
7 = Minor two lane highways.

The links include all interstate and federal highways plus major state routes. In addition, each node must be connected to at least one and preferably two links. It is anticipated that about 15,000 to 20,000 links will be in the complete network.

The computer programs serve the purpose of connecting roads and links and presenting parts of the network in an orderly fashion to assist in error detection.

2. Major Program Areas

The basic node and link definitions are placed in a single file, DATABASE1, with nodes first and links following. The subfiles for each state are ordered sequentially by a state FIPS code but are randomly ordered within a state. Links connecting nodes in two states are randomly input after the last state. For a state with state code YY, the program SELECT places all the nodes for a state and links with at least one node in the state in the file elements P5.NODEYY and P5.LINKYY (for states in the Northeast corridor, the file elements have the letter G inserted before the state code). The program LINKLOC adds location coordinates to the ends of the links in a state and places the result in an element P5.LINKLYY (P5.LINKMYY for the Northeast corridor). The program OUTSTE adds location coordinates for the links which have nodes in an adjacent state. The program TRBOTH transforms node and link data into a format where the plotter with a Hewlett Packard 9830 terminal calculator can use it to prepare outline maps of the road network. The programs NODROD and ONEROD print lists of the links associated with each road as an aid to detecting data errors.

The standard conventions for naming source programs, run elements, etc., are used for these programs. The programs are all designed for demand node terminal operation.

B. PROGRAM DESCRIPTIONS

1. Program SELECT

a. Elements in Program

The program consists of the main program elements with no subprograms.

b. Operating Procedures

The program is initiated by adding the run element @SELECT to the mainstream. Since the data files DATABASE1. and DB-. (which contains node locations) are always used, no modification to the run element is necessary.

After execution is initiated, the program requests "input state code." The two-digit FIPS code for the state is entered. The program then requests "input center lat lon S.W. lat lon." Four floating point numbers separated by commas are input. The first two are the approximate latitude and longitude (in degrees) of the center of the state. Geographic coordinates are transformed to flat earth rectangular coordinates using the input latitude for the conversion. A bias is added to the coordinate system so that the next input latitude and longitude form the center of the coordinate system. This point should be south and west of any part of the state considered so that the resulting rectangular coordinate system used for the nodes is everywhere positive.

The element P5.@SELECT should be modified so that the output is stored in the desired elements. This is accomplished by modifying line 1 to

@COPY,I OUTFILE.,P5.NODEYY

to store the node data and modifying line 2 to

@COPY,I OUTFILEA.,P5.LINKLYY.

to store the link data, where YY is the state.

c. Algorithms Implemented

The program reads input data and writes a header on the node file with state code, state center latitude and longitude, and offset distance from a point southwest of any point in the state.

The program then searches the file *DB4. until the proper state code is reached. Sequential records within that state are read for county FIPS code, county name (only the first eight characters of the county name are used) and the latitude and longitude of the center of the county rural population. Those are stored internally in arrays. The latitudes and longitudes are also converted into northings and eastings by multiplying the longitude differences for the county and state centers by 69.2, and the latitude differences by 69.2 times the cosine of the center of the state latitude.

The following data are then read for each node: state code, county code, node number in the county, a northing increment, an easting increment, an urbanized area indicator for the node, and a node name of up to 24 characters. A node number of 0 indicates the central node in a county. Here the increment distances are added to the northing and easting of the county center, as obtained from *DB4. to give a node northing and easting. If the node number is not zero, then the northing and easting in the record is added to the northing and easting of the 0 numbered node. (This requires having zero numbered nodes for that county.) The resultant node northing and easting are then placed on the node output file.

After all nodes for a state are found, the links for that state are copied from DATABASE1. to link output file. The end section of DATABASE1. is searched and all links with either node in the appropriate state are selected.

2. Program LINKLOC

a. Elements in Program

The program consists of the main program element with no subprograms.

b. Operating Procedures

The program is initiated by adding the run element QLINKLOC to the run stream. To ensure the proper output file, if the program is being run for state YY, line 3 of QLINKLOC should be @ADD,D *P5.NODEYY and line 11 should be @ADD,D *P5.NODEYY. No input data are read from the terminal. Line 1 of the element PLINKLOC should be @COPY,I *OUTFILE.,*P5.LINKYY.

c. Algorithms Implemented

The node file element for the state is read and the county code, county node number, and northings and eastings for each node are stored. Following this, each link from the link file element is read. A search is made for the node associated with each end of the link if the state code is the same as the state being considered. If a match is found, the northing and easting of the node is given to that end of the link. If no match is found, 0's are inserted for the northings and eastings and an error message is written on the standard output. The link data are then written on an output file element and the process continued until all links have been read.

3. Program OUTSTE

a. Elements in Program

The program consists of the main program element with no subprograms.

b. Operating Procedures

The program is initiated by adding the run element QOUTSTE to the run stream. To ensure the proper input, if the program is being run for state YY to add locations to links ending in state ZZ, then line 3 of OUTSTE should read @ADD,D *P5.NODEZZ and line 11 should read @ADD,D *P5.LINKYY. There is no terminal input. Line 1 of element PSELECT should read @COPY,I *OUTFILE., P5.LINKYY.

c. Algorithms Implemented

The algorithm for this program is similar to that for program LINKLOC except that the input node file element is for the specified adjacent state rather than primary state. Thus the only locations added are for the adjacent state.

4. Program NODROD

a. Elements in Program

The program consists of the main program with no subprograms.

b. Operating Procedures

The program is initiated by adding the element QNODROD to the run stream. If the program is run for state YY, then line 6 of QNODROD should read @ADD,D *P5.LINKYY. In reaponse to the terminal inquiry "input min max no min max es" the minimum and maximum northing and eastings of interest should be input as fixed point numbers separated by commas. Thus listings for only part of a state may be produced. If inputs for the entire state are desired, then the input -9999,9999,-9999,9999 will ensure the entire state area will be included. The output is a listing appearing on the standard output medium.

c. Algorithms Implemented

The data for all nodes in a state are read into core storage followed by that for all links. New nodes in ascending numerical order for county code and node number are selected. For each node, the link list is searched for all links associated with that node. The name, code and location are written on the standard output medium followed by a list of all links associated with that node. With each link the type of link, link quality, and route number are listed as well as the code and coordinates of the other end of the link.

5. Program ONEROD

a. Elements in Program

The program consists of the main program with no subprograms.

b. Operating Procedures

The program is initiated by adding the element QONEROD to the run stream. The lines to be changed in QONEROD and the terminal input are the same as for program QNODROD.

c. Algorithms Implemented

The algorithms implemented are the same as for program NODROD except that as each link is listed for the first time, it is recorded in an array. For each link listed in the array, further printing on the output medium is suppressed. Thus in the program NODROD each link is listed twice, once with the node at each end. In the program ONEROD each link is listed only once, with the node which has the lowest county code.

6. Program TRBOTH

a. Elements in Program

The program consists of the main program with no subprograms.

b. Operating Procedures

The program is initiated by adding the element QTRBOTH to the run stream. If the program is run for state YY, line 1 of the element QTRBOTH should read @ADD,D *P5.NODEYY and line 17 should read @ADD,D *P5.LINKYY.

If this is the x'th section of state YY to be considered, then line 1 of the element PTRBOTH should read @COPY,I *OUTFILE., *P5.TRNNYYX, and line 3 should read @COPY,I *OUTFILE., *P5.TRLKYYX.

When the program begins executing, the terminal prompts "input min, max no, min max east". Nodes will be selected only within the box specified by these limits. Four fixed point numbers separated by commas should be input.

The terminal next prompts "input border, margin, route switch, print switch." Four fixed points (variables NBORD, ISCLE,JRTNSW,IPRT) separated by commas should be input. The border value, NBORD, allows links to be selected where one terminus is within the node box just defined, and the other terminus is within a box increased in each dimension by NBORD (if NBORD is less then zero, a special read statement allows input of different border sizes along each boundry). A large value of NBORD will allow selection of all links connected with nodes in the basic box. The variable ISCLE allows the size of box used in plotting to be larger around each edge than the basic box by the amount ISCLE, in effect defining a border in the plotting area. It has no effect on the selection of handling of links, or their description in the output files. If the route number switch is one, in addition to the basic link

file, an additional link file giving quality indicator and route numbers is written. If the print switch IPRT is one, the nodes and links output are also listed on the standard output medium.

The terminal next prompts "input road quality, type selector and route selector." Three fixed point variables (IQL,ITP, IRT) separated by commas are input. If IQL is one, only links of designated quality specifications (more than four lane interstate, etc.) are selected. If the quality index is one, seven fixed point numbers separated by commas are input in response to a prompt; 1 indicates selecting a road of that quality, 0 indicates do not select one. If ITP is one, only roads of a certain type are used. In response to a terminal prompt three fixed point numbers separated by commas are input: the first selects interstate roads by inputting a 1, the second US federal highways, and the third, state routes. If IRT is 1, then only links in certain evacuation routes are selected, and if IRT is one, then the evacuation route numbers are read, five at a time, as fixed point numbers separated by commas; they are read into the array KRTRD. The reading is terminated by a zero.

In addition, the file element P5SRIRTS, which defines the evacuation routes, is read.

Each entry has three data elements, the first is the evacuation route number, the second the position entry in the particular evacuation route, and the third the number of the link being considered in the input file element P5.LINKYY.

c. Algorithms Implemented

The program begins by initializing certain variables and reading input data. The node file for the state is then read. Only nodes lying within the box defined by the input variable MINNO, MAXNO, MINES and MAXES are kept. In these nodes, the node code, northing and easting are written on one output file,

and the node number on another. These output files are generated in the format of a DATA statement in the BASIC computer language so that they can later be read into a Hewlett-Packard calculator for plotting. A simple change in two output format statements would allow these files to be written in another form.

The link file is then read. As each link is read, several tests are made. The first is that at least one terminus is within the box defined by MINNO, MAXNO, MINES, MAXES. The second is that both link terminii must be within the extended box defined through the variable NBORD. If the road quality switch, road type switch or route number switch is one, the appropriate tests are made for retaining the link.

If one end of the link extends outside the border of the node box, that link is truncated at the point where it intersects the boundry of the node box. This is done through a series of tests which first determines which side of the box is intersected by the link, and then computes the intersection point of these two lines. This intersection point is then used at the link terminus. The link terminii are then written to output file MW in the form of a BASIC DATA statement. If route numbers are to be added, link characteristics are stored in data arrays. The process is continued until all links for the state are read.

If route numbers are to be written, the output information contains the center point for the link, direction cosines of the link, and link quality, type and route number. Since more than a single road may run between two nodes, it is necessary to provide special output so that route numbers are not overwritten. This is accomplished by searching through all subsequent links when a particular link route number is written to find any other links with the same node numbers for end points. If any are found, these route numbers are also output

with an indicator to show they are additional roads between the same two nodes. A flag is set so these links will not be used later.

C. SPECIAL FILES

1. Input data

The basic node and link data for all states are in the file DATABASE1. The data for nodes are stored by state in increasing state number. The digit 96 in columns one and two is used as a separator for state node data. This is the first entry in the file and after each link. The digit 99 in columns 1 and 2 appears next as a separator between node and link data. The link data are grouped by states ordered by state number. The separator 97 appears as the first entry in the link portion of the file, after the link portion of the file, and then after the links for each state. Following this the separator 98 is entered, along with link data for links where the origin is in one state and the end in another.

The node file entries are state FIPS code (A2), county FIPS code (A3), (3X), node number in county (I2), node county northing, miles (I5), node county easting, miles (I5), node urbanized area indicator, 1 if urbanized area (I2), node name (A24).

The link file entries are state FIPS code for link origin (R2), county FIPS code for link origin (A3), (2X), county node number for link origin (I2), (1X), state FIPS code for link end (A2), county FIPS code for link end (A3), (2X), county node number for link end (I2), (9X), quality index (I2), type index (I1), route number (I5).

2. Processed Node and Link Files

The node files for a state are created by the program SELECT. The first line is a header in the following form:

state FIPS code (A2), latitude for center of state, degrees (F9.4), longitude of center of state (F9.4), a latitude southwest of any point in the state (offset point) (F9.4), a longitude southwest of any point in the state (F9.4), northing from offset to center point, miles (F9.4), easting from offset to center point, miles (F9.4), scale north, miles/degrees (=69.2 here) (F8.4), scale east, mile/degrees (=69.2 · cos (center latitude)) (F8.4).

The set of node entries are of the format: state FIPS code (A2), county FIPS code (A3), (3X) county node number (I2), state node northing, miles (I5), state node easting (I5), node urbanized area indicator (I2), node name (A24), node latitude (F9.4), node longitude (F9.4), first part of county name (A8). Note that node name entries have the same format as the basic input data file.

The node file is terminated by an entry with the digits 99 for the state FIPS code.

The link file elements output from program SELECT has no header and link entries are in exactly the same format as in the input file DATABASE1. The links with both ends in a state come first, the separator 98 is used in columns 1 and 2 and the links with only one end in a state follow, terminated by a 99 is columns 1 or 2. For state YY these file elements are denoted by P5.LINKYY or P5.LINKGYY.

Links with end locations attached are output from programs LINKLOC and OUTSTE, and for state YY are denoted by P5.LINKLYY or P5.LINKMYY. They have no header. The format is: state FIPS code for link origin (A2), county FIPS code for link origin (A3), (1X), county node number for link origin (I2), number of link in the state if node is in the state for the node origin (I4), state northing for link origin (I5), state easting for link origin (I5), (1X), state FIPS code for link end (A2), county FIPS code for link end (A3), (1X), county node

number for link end (I2), number of link in state if link end is in state (I4), state northing for link end (I5), state easting for link end (I5), (10X), link quality index (I2), link type index (I1), link route number (I4). Again the separator 98 is used after all link entries with both ends in the state, and 99 at the end of all entries.

Chapter VI

PROGRAM AREA P9., MILLER-S FALLOUT MODEL

A. INTRODUCTION

1. General Area Covered

This series of programs implements the MILLER-S fallout pattern prediction model on the Sperry Univac 1100 computer. This model was developed by Dr. Carl Miller based on a detailed and extensive analysis of fallout pattern data. It is unique among fallout models because several of the parameters determining fallout pattern shapes can be stochastically selected. The fallout pattern is obtained as a sum of ten subpatterns, and parameters describing these subpatterns may be randomly obtained. Thus, successive runs with the model under identical input conditions can produce quite different fallout patterns.

The model uses a set of wind speeds and directions input for up to 50 different altitudes. These winds may be input up to 10 different times. Input variables are also used to describe weapon parameters such as yield and fission fraction.

The model is described and defined in [Ref. 9]. It is assumed here that the reader is familiar with this Reference. The documentation does not repeat this material in this Reference.

A computer program to implement the fallout model as defined in the earlier reports was written, under the model development contract, for the CDC 3600 computer and stored

at the DCPA Computer Center. In this effort, this program was converted to the Sperry Univac 1100 machine, adapted to terminal operations, updated to include the changes indicated in the Fallout Modifications Report, and checked against hand calculations in this report. Several errors in the original program were found; thus this program as stored was not a correct implementation of the original model. In addition, the adaptation of the original program was restructured and divided into several subroutines. Besides a general separation of various activities, this restructuring separated those calculations which were made for a particular weapon and set of wind conditions and those calculations which were unique to each individual monitoring point. This restructuring was necessary to allow adequate flexibility in the control of the calculations flow. Those sections where the calculations differed from the original model are indicated in the code, but the structural changes are not flagged in the code since their nature is evident and they do not influence the numerical values of the model predictions.

2. Summary of Major Program Areas

Three separate variations of the implementation of the MILLER-S model are presented here. The first, MILLGD, allows calculations of fallout doses on a grid from a single weapon. In this implementation, the input data form an element in the file P9. Changes in input parameters can be readily accomplished through the text editor. The second version, MILINT, is developed for interactive input of control parameters through a terminal. The third version, HEXGON, allows calculations of fallout on a grid with an input of up to 50 weapons. An auxiliary program, LEVGRD, is available to convert wind data from a global polyconic grid for specific data to wind data on a 2° grid covering the United States in a form

usable by the MILLER-3 model. Another set of programs allows plotting of wind grid results on a Hewlett-Packard plotter.

B. PROGRAM DESCRIPTIONS

1. Program MILLGD

a. Elements in Program

The program consists of the main program MILLGD and the following subroutines:

MILSIN - To input run parameters and winds

SUBCLD - To calculate those parameters associated with a particular weapon and set of winds

XYDOSE - To calculate the dose at a single point

GENRNO - To generate a set of random numbers in a uniform distribution in a specified interval

RANCL - To drive the Univac random number generator.

The following common blocks are used for communication between subprograms:

/SUBPAT/ - For those parameter values which are computed for each weapon

/MILLPT/ - For those parameters unique to each monitoring point

/MILLIN/ - For input parameters.

The usual convention is adopted for various types of elements. A source element is indicated by an N prefixing the subprogram; a relocatable element by the prefix R. The run stream to produce an absolute executable element is VMILLGD and the absolute element is denoted by SMILLGD. The run stream to execute the program is QMILLGD, and the post processing run stream is PMILLGD. Since each of the common variables is described either in the published program documentation, or in the list of input parameters described below, these will not be repeated here.

b. Operating Procedures

(1) General

The standard method of element prefixing is used in these programs. However, a set of standard runs is contained in elements of P9. called PROBLEM A through PROBLEM I. No user response is needed once the input element is defined. Output is stored on an output file element defined by element PMILLGD. The current name is *P9.DOSFILE.

(2) Input Elements

Line 1 - Grid Definitions

Variables NGDX, NGDY, XMIN, YMIN, DELGX, DELGY
Format (2I10, 4F10.0)

This line defines the grid of monitor points with NGDX, NGDY, the number of intervals in the X and Y directions, XMIN and YMIN the minumum values assumed on the grid in the X and Y direction, and DELGX, DELGY the grid spacing in the X and Y direction. The weapon is assumed to be at the grid origin. The grid directions define the wind direction when the direction from which the wind blows is given in degrees counterclockwise from the positive Y axis. Thus, for a wind direction of 270 degrees, the wind blows from the negative X direction to the positive X direction. On normal geographic applications, the positive X direction is east and positive Y direction is north so the wind is given as degrees counterclockwise from the north.

Line 2 - Print and Random Number Seed Control

Variable ISEED, IPRNTA, IPRNTB, IPRNTC, IPRNTD, IPRNTE
Format (6I5)

ISEED = 1 randomly obtains a random number seed for each run so the string of random numbers for each run is different and non-repeatable; ISEED=0 uses a value of random number

seed fixed in the code. Since the random numbers are all used before calculations for any grid points are started, ISEED=0 allows several runs with different grids but the same weapon parameters.

IPRNTA = 1 prints input data values on the standard output medium

IPRNTB = 1 prints a large amount of intermediate subcloud descriptive data on the standard output medium

IPRNTC = 1 prints final grid results on the standard output medium

IPRNTD = 1 writes final grid results on a output file which is saved

IPRNTE = 1 prints doses for each subcloud at each grid point.

Line 3 - MILLER-S 2 Model Parameters

Variables W, B, HZERO, FM, GROUND, DELZ, KIND, KFACSW

Format (6F10.2,2I1)

W = weapon yield (kilotons)

B = weapon fission fraction

HZERO = height of burst (kilofeet)

FM = effective target weapon weight (kilotons). This variable gives the mass of material, exclusive of the ground, which becomes entrained in the cloud to effect fallout formation.

GROUND = surface altitude (kilofeet)

DELZ = nominal thickness of an air layer (kilofeet). The variable is the integration interval in integrating subclouds' downwind paths through the various wind values as a function of altitude.

KIND = uses randomly selected values for generating subcloud parameters, if 1 selects "50th percentile." Specifies values for subcloud parameters and suppresses stochastic effects.

KFACSW = selects method of weapon k-factor selection,
0 use k-factor as in the original model
1 set k-factor always to a value of 1930 R/hr/KT/mi^2
2 set average k-factor value to 1930 R/hr/KT/mi^2
(See section below for discussion of k-factor selection).

Line 4 - Type of Wind Input

Variable WKEY

Format (A1)

WKEY = if equal C use constant winds, if equal V use winds variable with time and altitude.

Line 5 - (if WKEY=0)

Variable TIME(2), TIME(1)

Format (2P10,0)

TIMU(2) = wind speed in miles/hr

TIMU(1) = direction wind blows from in degrees counter-clockwise from positive Y axis (north).

Line 5a - (if WKDY=V - Number of Times for Variable Wind Input

Variable MTIMS

Format (I5)

MTIMS = number of times for variable wind input.

Line 6 - Time for Variable Wind Input

Variable (TIME(J), J=1 MTIMES)

Format (7F10.0).

Line 7 - Number of Altitudes for Variable Wind Input

Variable NALTS

Format (I5)

NALTS = number of altitudes for wind input.

Line 8 - Altitude for Variable Wind Input

Variable (ALT(J), J = 1,NALTS)

Format (7F10.0)

ALT(J) = altitude of Jth wind input (kilofeet).

Line 9 to 9+ MTIMES · NALTS Variable Wind Input

Variables for J = 1 to MTIMES

(WIND(J,K,3),WIND(J,K,1)K = 1,NALTS)

Format (2F10.0).

Input wind speed and direction by pairs for increasing altitudes and a constant time, and then for increasing time:

WIND(J,K,2) = wind speed miles/hr.

WIND(J,K,1) = wind direction in degrees counter-clockwise from positive Y axis (north).

(3) Selection of Overall Weapon Fission Output

The overall amount of fission deposited by the MILLER-S model is the sum of fission deposited from each of ten subclouds. The logarithm of the fission output multiplier for each subcloud is selected from a uniform distribution with the end points of the interval different from each subcloud. The fission for each subcloud is the product of the fission product multiplier for each subcloud times a value J_T° (k-factor) which is a function of height of burst and entrained material in the cloud. The sum of fission product multipliers, S_μ, could vary from 0.0758 to 2.4 with different random number draws. If the sum is over 1, the subcloud multipliers are decreased proportionately to make the sum 1.

The value of J_T° is a value determined directly from fallout pattern observations including surface roughness and instrument calibration effects. The value adopted is felt to represent the maximum value J_T could achieve, with most weapon

outputs somewhat below their upper bound. To change the results to radiation over an infinitely smooth plane (the type of output usually given from fallout models) would require multiplying by 4/3 for each of these effects, or multiplying the predicted output by $(4/3)^2$. For a surface burst the value of J_T° used is 1230. Multiplying by $(4/3)^2$ gives 2186 for the maximum value of J_T° corrected for these two effects, which is the type of output given in most other fallout models.

A computer program, MUDIST, was written to study the distribution of values of S_μ. Figure 1 presents a histogram of S_μ from 20,000 trials. The mean of all trials is 0.687. The value of S_μ was greater than one 7.75 percent of the time. If the values greater than 1 are truncated to 1, a mean value of 0.679 is obtained. This gives an average value of total fission output equal to 2186 x 0.679 = 1484. A National Academy of Sciences Report [Ref. 13] recommends use of a k-factor of 1930. If the doses predicted by the MILLER-S model are multiplied by 1930/1484, a mean value J_T equal to the NAS recommendation is obtained. An input value of KFACSW = 1 allows this to be done. A consequence of this option is that the maximum value of fission output possible in the model is 2186 x 1930/1484 = 2842, close to the total fission output from a weapon (of 2900) adopted in the NAS report. This would imply almost all of the weapon fission products contributing to local fallout. However, of the 13 measurements of fission deposited from the 5 weapons tests adopted by the NAS report to produce the 1930 value, 3 measurements were rejected because they were above the 2900 value. (The values reported were as measured and included the instrument and ground roughness factor, so the actual rejection criteria were measured values of 1620 and above). Thus, these large possible values of J_T are not inconsistent with reported measurements. The third use option, selected by a value of KFACSW of 2, suppresses the evaluation of total weapon output and forces all values of

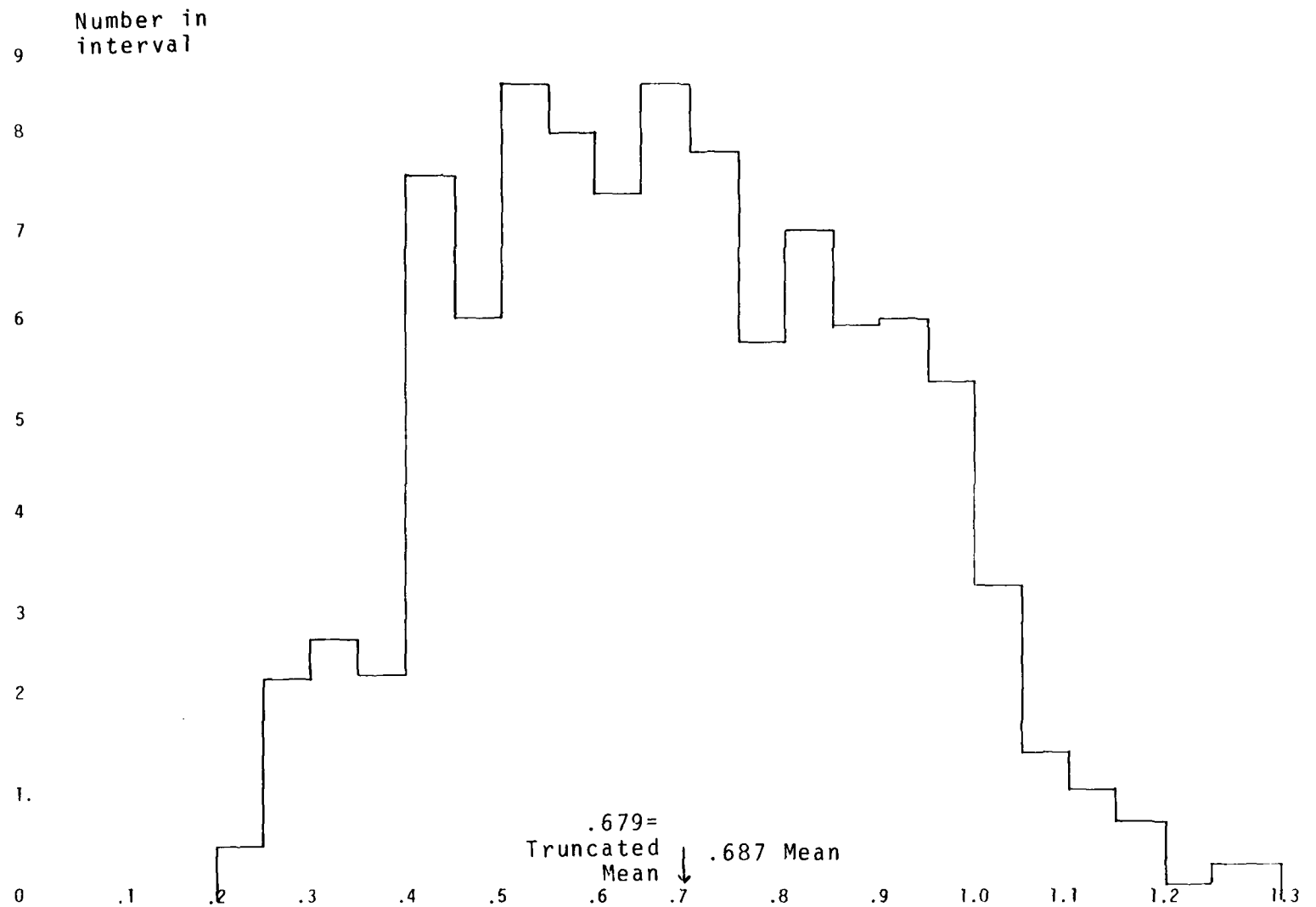


Figure 1. HISTOGRAM OF SUM OF SUBCLOUD ACTIVITY MULTIPLIERS FOR MILLER-S MODEL

total weapon output to 1930 by multiplying each subcloud fission product multiplier by $1930/S_u$. Thus, a variation between subclouds is allowed while the total weapon fission output is at the standard value. A selection by the user of one of these three options should depend partly upon the users viewpoint of an appropriate value of a k-factor and partly upon the context within which the model will be used.

c. Algorithms Implemented

The summary of Volume II of [Ref. 9] defines the model through a description of the 40 steps into which the calculation is divided and forms the basic documentation of the model. The algorithms in the computer program are a straightforward implementation of these steps, except for Step 12 which performs a numerical integration through the specified wind yield to find the locations of the center of each subcloud. The integration is achieved by using the wind speed and direction at the start of each altitude step, specified by the height increment DELZ, and the time spent in this altitude increment, computed in step 11, to find the travel in the X and Y direction in this altitude step. The total travel is obtained by simply summing the increments. The wind speeds and direction at each altitude are obtained by linear interpolation, in both time and altitude, from the nearest values available from the input data. Modifications made to the original program are described in Section E of this chapter.

2. Program MILINT

a. Elements in Program

This program is the same as program MILLGD except that the parameters are input interactively from a terminal in response to prompting from the program. The elements are the same as for program MILLGD except for the input subroutine

which is called MILINT. The usual convention is adopted for the various types of program and run elements.

b. Operating Procedures

Program operation is initiated by adding the element P9.QMILINT to the run stream. Since all input is interactive, no input data file is needed. The series of prompts are self-explanatory to allow effective program operations. Output is saved in the file element *P9.DOSFILE.

c. Algorithms

The same algorithms as in program MILLGD are used.

3. Program HEXGON

a. Elements in Program

This program is the same as program MILLGD except that a number of weapons at different locations may be input. Although it is not an essential limitation, the program is currently restricted so that all weapons are described by the same parameters and all winds are the same. The subcloud parameters for each weapon, however, are different and are obtained by a different string of random numbers.

The parameters defining output of each weapon are stored in the main program. For each weapon there are 305 values stored. The maximum number of weapons is currently limited to 50, thus 15,250 storage locations are allocated for this purpose and represent a storage requirement in addition to that needed for program MILLGD. Since the input of weapon locations is in the main program, all subprograms and all block common is exactly as in program MILLGD.

b. Operating Procedures

The operating procedures are exactly the same as for program MILLGD except that a set of input lines describing weapon locations are inserted before any other input. These lines are as follows:

Line 1 - Number of Weapons

Variable NWPN
Format (I5)

The number of weapons is limited to 50 or less. If the value of NWPN is input as 9999, then 50 weapons all located at the origin are assumed and the fission fraction of each weapon is divided by 50. In this case no further weapon input is needed. This gives an approximation to the expected dose from a weapon.

Line 2 - To NWPN + 1 Weapon Location ($1 \leq NWPN \leq 50$)

Variable XWPN (I), YWPN,(I) I = 1,50
Format (2F10.0)

The weapon location is in relation to the origin of the coordinate system. The same conventions for the grid and weapons as described for program MILLGD apply.

c. Algorithms Implemented

The algorithms implemented are the same as for program MILLGD with the exception of the following additions to the main program:

(1) The subroutine SUBCLD is called for each weapon and the parameters describing the weapons are stored.

(2) For each grid point, the X and Y distances for each weapon are computed. For each weapon stored, parameters are placed in the common block /SUBPAT/, and the subroutine XYDOSE is called. The doses for all weapons are summed and reported as the dose at that grid point.

C. SPECIAL FILES

1. Block Common Procedures

The common blocks for the MILLER-S programs are entered by the Univac FORTRAN INCLUDE statement. Those blocks are in the element P9.INCOMM made available to the MILLER-S programs by the System PDP processor.

2. Plotting Programs for the Hewlitt-Packard Plotter

Several programs have been developed to allow plotting fallout patterns on the Hewlitt-Packard 9862 plotter used in conjunction with the Hewlitt-Packard 9830 terminal. The Univac program TRSGDS transforms fallout grid data into a format usable by the H.P. calculators. The input file element *P9.DOSFILE is transformed to an output file element *P9.HPDOSP which is later transmitted to the H.P. calculator.

All grid points with a dose less than a specified value, currently 1 R/hr. at H+1 hours, are deleted in the transformation. The element P9.TRSGDS includes control lines for file assignments, FORTRAN compilation and mapping. The element P9.QTRSGDS does file assignments but uses the absolute element P9.STRSGDS for execution, by-passing compilation and mapping.

The plotting is accomplished through the execution of a BASIC program on the H.P. calculator. This program is stored in the element P9.HPDSPT. To accomplish a plot, the BASIC program HPDSPT and the grid plots HPDOSP (these data are in the format of BASIC data statements) are transmitted from the Univac 1100 to the H.P. calculator, compiled and executed on the calculator.[1]

[1]A simple way of effecting the transmission is to enter the Univac text editor with the element P9.HPDSPT and P9.HPDOSP. The command P! is given to the text editor by depressing the f8 key on the HP calculator and again depressing the same key after transmission. The instructions COMP and RUN executed on the calculator will then accomplish the plotting. In order to achieve a plot without distortion the ratio of total XX distance interval to total Y distance interval on the plotter bed should equal the ratio of the variable XGDX/XGDY in the program MILLGD.

3. Wind Processing Programs

Daily wind reports are available from Global Weather Control (GWC) on a grid of 1840 points covering the Northern Hemisphere. Wind speed or direction are reported at 700, 500, 300, 200 and 100 millibars for each point in the grid. A set of 12 historical winds, one for one day of each month, have been selected by R. Mason of Command and Control Technical Center and collected into a set called "most probable winds." These winds are stored on the 1100 in a file called LASH*MASON-WINDS.

The program P9.LEVGRD selects the winds for a specific month, interpolates from the GWC grid to a 2 degree grid covering the United States, and writes the resulting winds at each level on an output file element. The file element is defined by the element P9.PLEVGRD. These output winds may be listed to select appropriate real winds for input into the MILLER-S model. The grid conversion and interpolation routines are the same as described for the element P12.RAWGRD.

D. EXAMPLES OF PROGRAM USE

This section presents the results of several executions of the MILLER-S model over a 28x20 point grid. The H+1 dose rate in R/hr. is presented at the grid points using the following scale:

Blank	less than 1
-	1-10
A	10-20
B	20-40
C	40-60
D	60-80
E	80-100
F	100-150
G	150-200
H	200-300
I	300-400
J	400-500

K	500-600
L	600-1,000
M	1,000-10,000
N	10,000-∞

Figure 2 presents the results of a run of the MILLER-S model on a five mile grid using the program MILLGD for a set of weapon parameters and wind data which are given in the users manual of the model description. The weapon yield is 3.4 MT and the fission factor = 0.217. The weapon is surface burst at ground level. Wind data are input 7 times, from -4 to 21 hours, and at 38 altitudes, from 0 to 99,000 feet. The following table shows the winds at time 0 at 10,000 ft. intervals.

Alt. (Kft.)	Wind Speed (mph)	Direction (deg.)
0	22	50
10	23	100
20	12	140
30	14	170
40	46	220
50	29	240
60	17	80
70	30	90
80	48	100
90	48	100

As can be seen the wind at ground level is blowing to the southwest and gradually swings clockwise with increasing altitudes until at 50,000 ft. altitude it is blowing almost due east. It then suddenly shifts and blows almost due west. Recalling that the positive X axis on the grid is to the east, and the positive Y axis is to the north, one would expect fallout to be deposited in the two quadrants above the axis. Figure 2 shows the deposition with a five mile grid spacing when the model is run with a standard seed. In these runs, the original method of measuring J_t^o is used. The total weapon fission output is 1350 R/hr./Kt/miles^2 which is 0.6275 times the maximum

of 2150. In Figure 3 the same weapon is presented on a ten mile grid to illustrate the total extent of the deposition of doses above 1 R/hr at H+1 hours. In Figure 4 the same weapon is presented on a one mile grid to illustrate in more detail the region near ground zero. In Figure 5 the WSEG-10 biological dose is shown on a five mile grid. The letters indicate dose in Roentgens, rather than Roentgens/hour, but for the same numerical ranges.

The fallout patterns in the MILLER-S are obtained by summarizing the doses from each of ten subclouds. The following table gives the total fission activity in each subcloud and the X,Y coordinates of the center of its subcloud. (Since the subcloud may be assymetrical, the center is not the geometric pattern center but the center of the subcloud coordinate system.)

Subcloud Number	Activity Subcloud $R/\mu_r/Kt/Mile^2$	X Coordinate of Center (Miles)	Y Coordinate of Center (Miles)
1	10	-0.8	0.2
2	20	-3.3	0.4
3	165	-7.7	0.2
4	64	-54.8	22.1
5	661	-4.5	48.0
6	212	-7.7	63.1
7	74	-12.3	65.6
8	37	-153	65.5
9	39	65	142.3
10	63	-207	56.0

Figures 6 through 10 present other runs with different strings of random numbers where the subcloud parameters are different. In the runs the total weapon fission output is 1527,1814,1435,1360 and 678 R/hr/Kt/miles^2, respectively. Figure 11 is a run for the same conditions except that the mid-range values of the various distributions are selected.

A set of runs was made with a wind of 15 mph constant in both altitude and time blowing from west to east. A surface burst 1 MT weapon with a fission fraction of 0.5 was chosen to

check against the hand calculations for the same conditions given in the Fallout Modification Report. Figure 12 presents the pattern on a ten mile grid. Figures 13 through 18 present a set of another six patterns generated under the same conditiors as the "observed dose." In these runs, the k-factor was 1916,1122,1112,1327,1124,1373. Figure 19 presents a pattern under the same conditions as those just presented but using the 50th percentile value in a non-stochastic run of the model.

A set of Figures is presented next to illustrate the effects of increasing wind shear. Figure 20 presents the observed dose patterns for a 1 MT weapon with a standard seed, as in Figure 12, but with 15 mph winds which at 0,40,60,80 and 100 kilofeet is 270 degrees, and at 20 kilofeet is 240 degrees. Figure 21 has the wind at 270 degrees at 0,60,80, and 100 kilofeet but at 240 degrees at 20 and 40 kilofeet. As is seen, these patterns are not too different in gross shape from those of Figure 12, but are inclined at about 30 degrees once the pattern is about 50 miles downwind. In Figure 22 the ground wind is shifted to southeast and the wind at 60,000 feet and above to north. The angles are 300° at 0Kft, 240° at 20Kft, 240° at 40Kft, 180° at 60Kft, 180° at 80Kft, 180° at 100Kft. Although the effect of the ground wind shift is evident for small downwind distances, the pattern remains surprisingly like Figure 21. In Figure 23 a significant change in direction between 20 and 40 kilofeet is introduced and the pattern is markedly affected. Here the wind directions are 300° at 0Kft, 270° at 20Kft, 210° at 40Kft, 180° at 60Kft, 180° at 80Kft, and 180° at 100Kft. In Figure 24 the winds of Figure 23 are repeated except that the wind values at 20 and 40Kft are interchanged. The pattern switches from concave to convex in overall shape with this change in winds. It should be remembered that this progression of wind direction effects is for a single set of weapon parameters and string of random numbers where, for example, the subclouds are originated at the same altitude in

each of these calculations. To illustrate the differences which might occur from a different draw of random numbers, Figure 25 repeats the wind conditions of Figure 23 but with a different set of random numbers.

Daily meteorlogical data on a grid are available at 700, 500,300,200, and 100 millibars which can be equated to 10,20, 30,40, and 60 kilofeet measurements. The MILLER-S model was used with wind input at these levels plus a wind at 0 Kft. equal to the wind at 10 Kft. and the wind at 100 Kft. equal to the wind at 60 Kft. added. Winds selected from the set of most probable winds of R. Mason for the month of October were used to try the MILLER-S model with representative real winds available from gridded meteorological reports. Figure 28 presents patterns from an October wind over Washington D.C., which was selected as typical of the many locations where the wind direction was quite constant.

The winds as a function of altitude were:

Altitude (Kft)	Speed (mph)	Direction (degrees)
10	33.0	249.1
20	71.2	241.2
30	117.9	247.1
40	124.1	249.6
60	69.8	245.5

The wind reported was in knots but was used as miles/hr; thus the actual winds were even a little higher than those used. In order to present more of the pattern, Figure 29 repeats the calculation on a ten mile grid. As can be seen, with this high wind the value of ten R/hr at H+1 hours extends as far as 300 miles downwind. Figure 30 presents the same condition for a different string of random numbers.

The winds at Stockton, California for October were selected as representative of a different extreme, low wind

speeds and significant changes of wind direction with altitude. The winds in this case are given in the following table.

Altitude (Kft)	Speed (mph)	Direction (degrees)
10	5.9	192.3
20	4.3	125.9
30	1.1	295.5
40	15.3	247.6
60	9.3	273.0

The resulting pattern is shown on a ten mile grid in Figure 32, and for two other sets of random numbers in Figures 33 and 34. As can be seen, a degree of variability comparable to the patterns in Figures 2 to 8 is obtained.

A series of calculations was made for seven 1 MT weapons with a fission fraction of 0.5 in a hexagonal pattern. Figure 35 shows the patterns obtained with a 15 mph constant wind with the distance across the hexagon equal 20 miles. Local regions of higher dose are still evident here. In Figure 36 the seven weapons are in a larger hexagon, with the distance across the hexagon 40 miles, and for Washington, D.C. winds. Figure 37 shows the same pattern for Stockton, California winds. It should be mentioned here that if the stochastic features of the MILLER-S model do in fact represent actual variation between weapons, then these figures present a view of the fallout patterns downwind of multiple bursts which have not been previously seen, either analytically or experimentally.

In Figures 38 and 39 the patterns represent the results from 50 collocated 1 MT weapons with a fission fraction of 1/50th of 0.5. They are for Washington D.C. and Stockton California winds. These patterns approximate the expected dose for these wind patterns. However, with the large weapon to weapon variation, the meaning of these expected doses must be carefully interpreted.

Figure 2. H+1 DOSE RATE FOR 3.4 MT WEAPON USER MANUAL WINDS ON 5 MILE GRID WITH STANDARD SEED

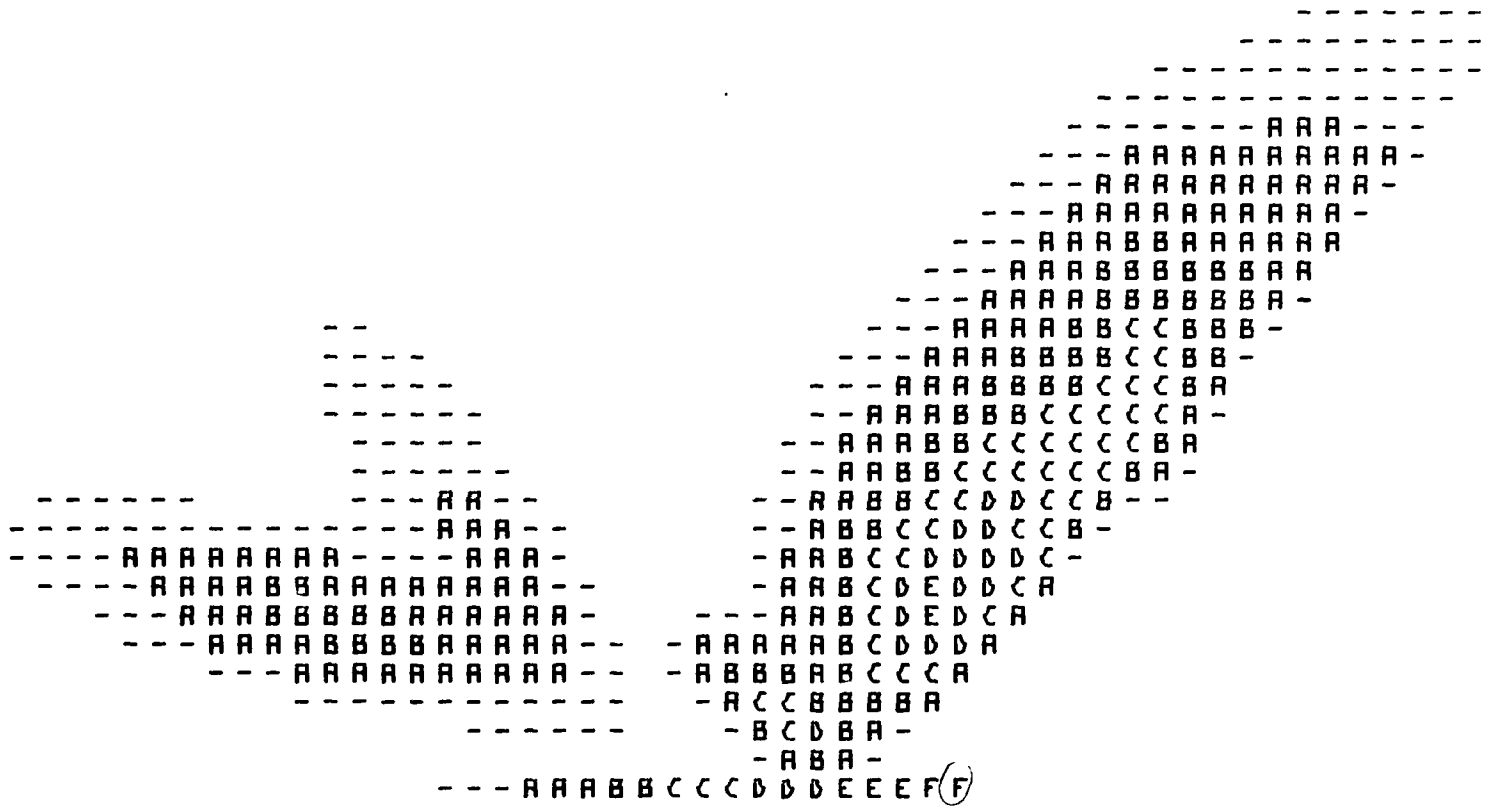


Figure 3. H+1 DOSE RATE FOR 3.4 MT WEAPON FOR USER MANUAL WINDS ON 10 MILE GRID WITH STANDARD SEED

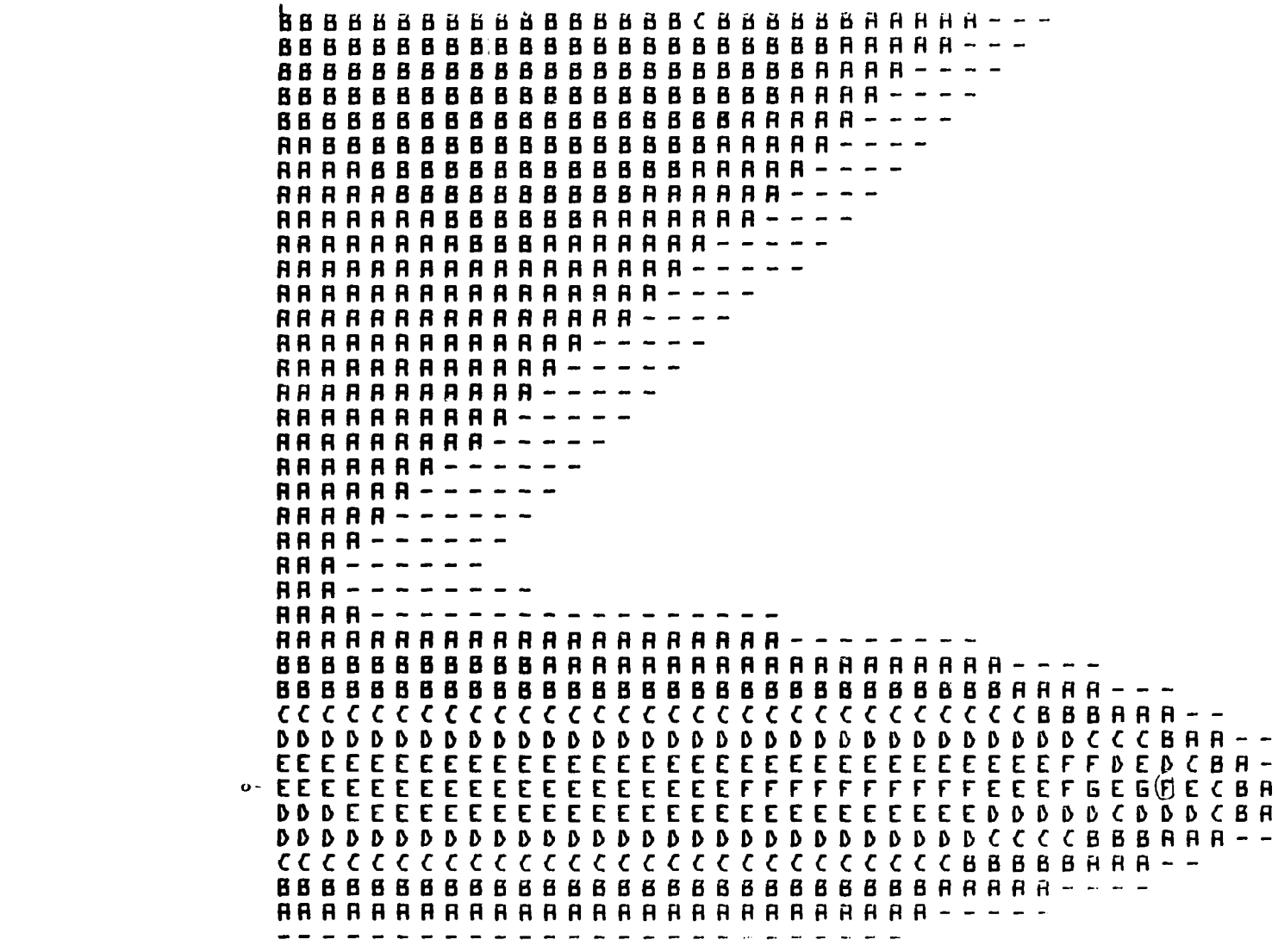


Figure 4. H+1 DOSE RATE FOR 3.4 MT WEAPON FOR USER MANUAL WINDS ON 1 MILE GRID WITH STANDARD SEED

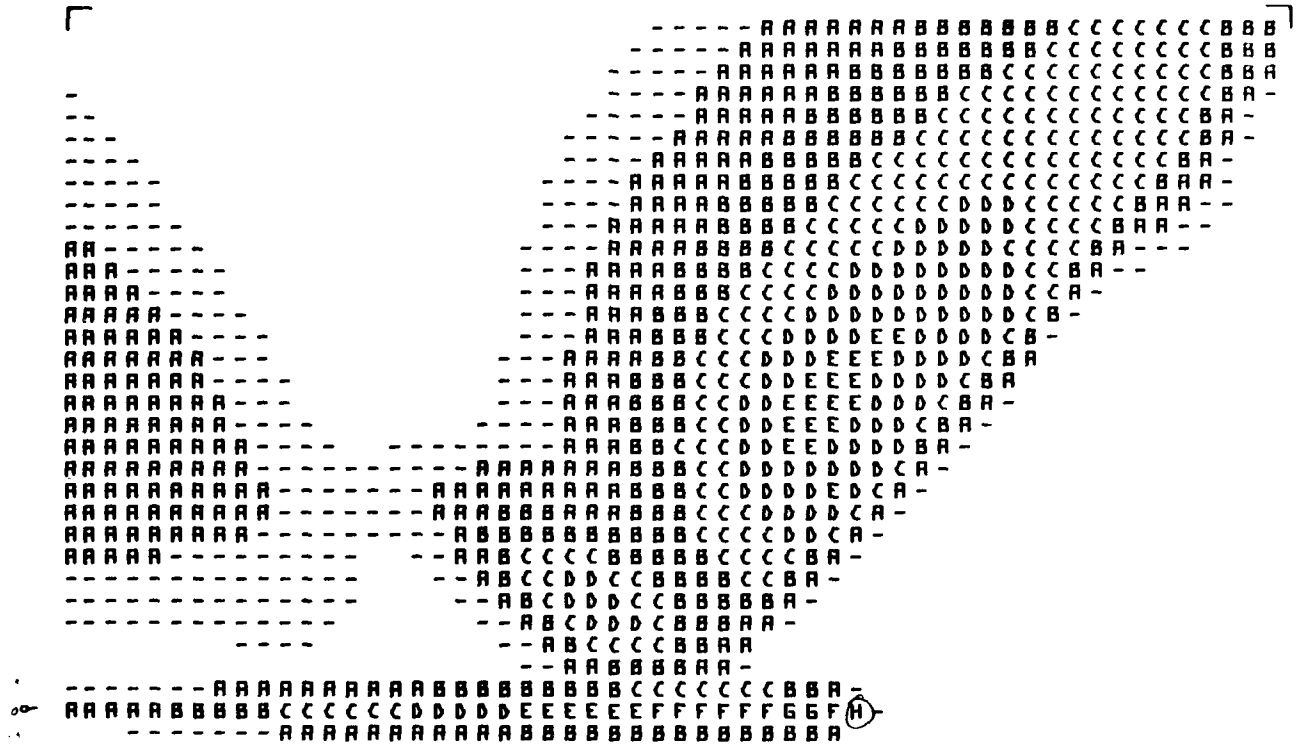


Figure 5. BIOLOGICAL DOSE FOR 3.4 MT WEAPON FOR USER MANUAL WINDS ON 5 MILE GRID WITH STANDARD SEED

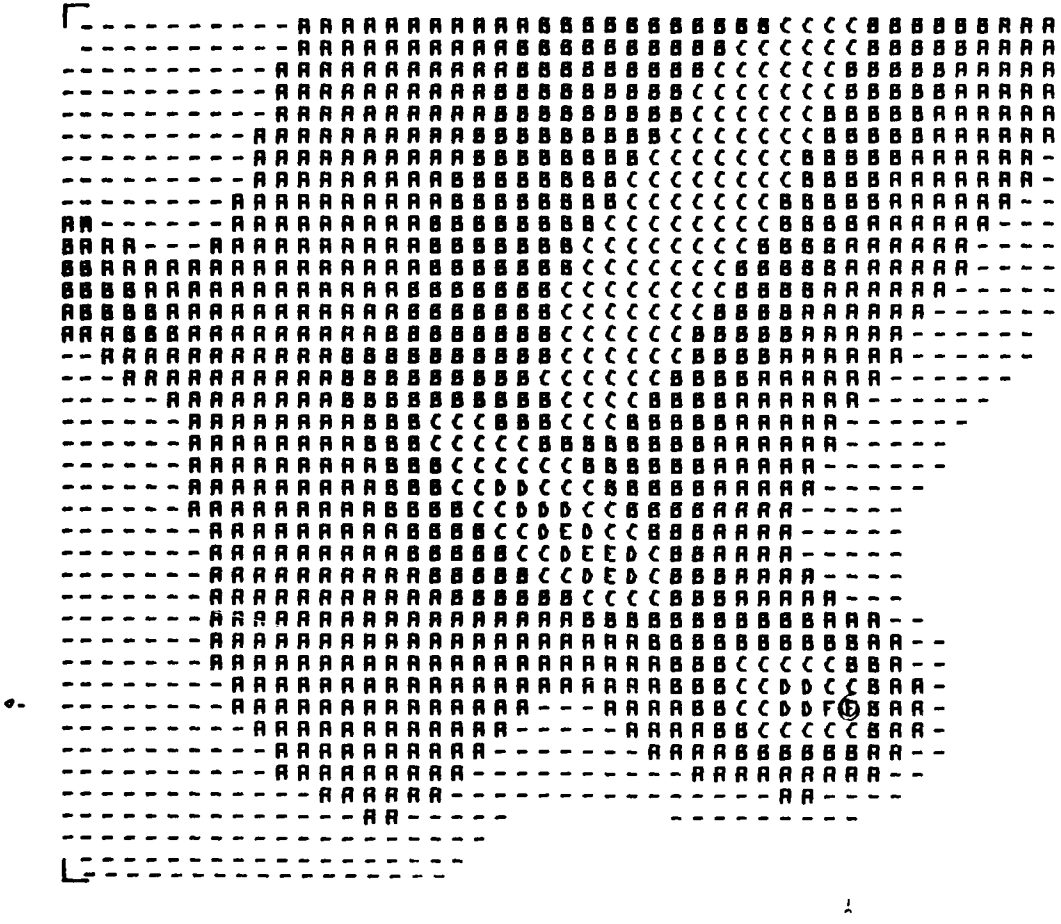


Figure 6. H+1 DOSE RATE FOR 3.4 MT WEAPON FOR USER MANUAL WINDS ON 5 MILE GRID WITH RANDOM SEED

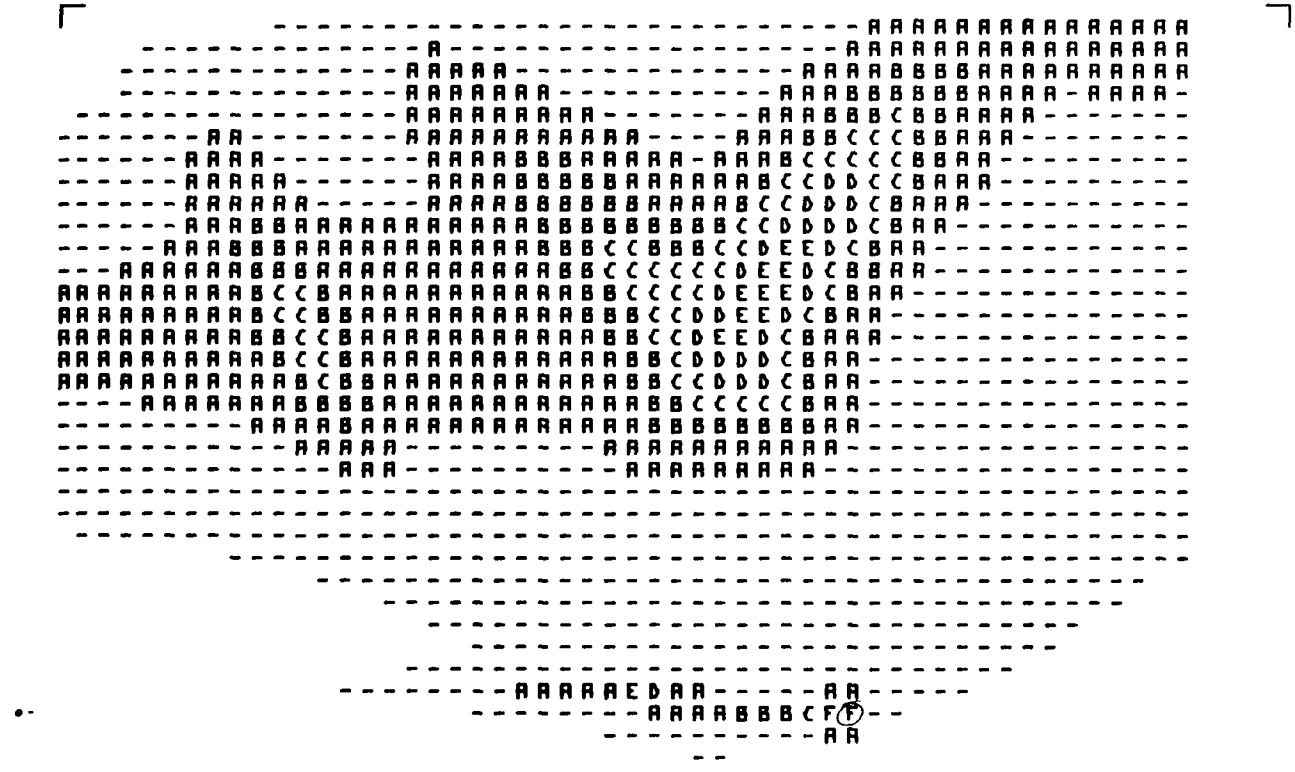


Figure 7. H+1 DOSE RATE FOR 3.4 MT WEAPON FOR USER MANUAL WINDS ON 5 MILE GRID WITH RANDOM SEED

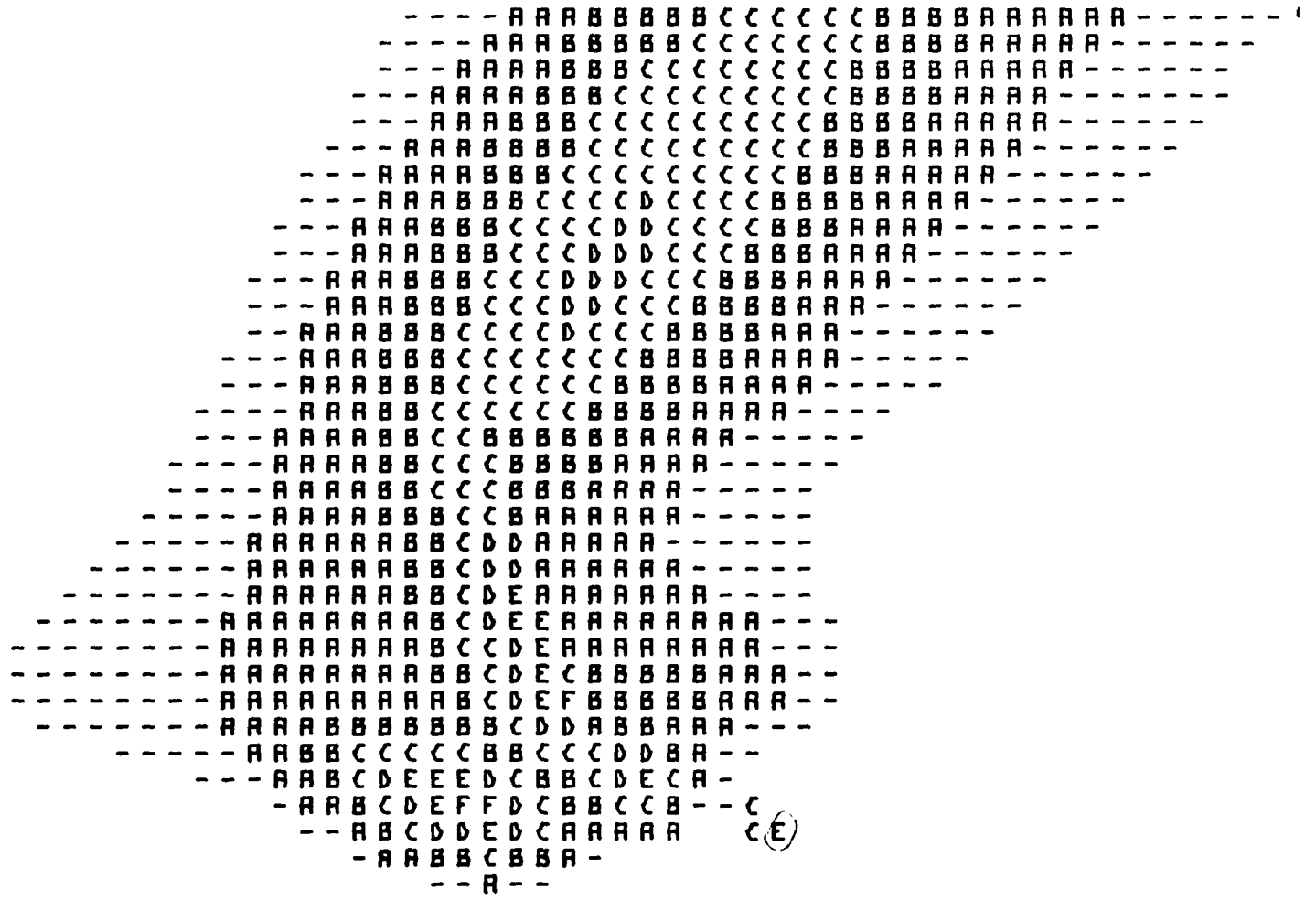


Figure 8. H+1 DOSE RATE FOR 3.4 MT WEAPON FOR USER MANUAL WINDS ON 5 MILE GRID WITH RANDOM SEED

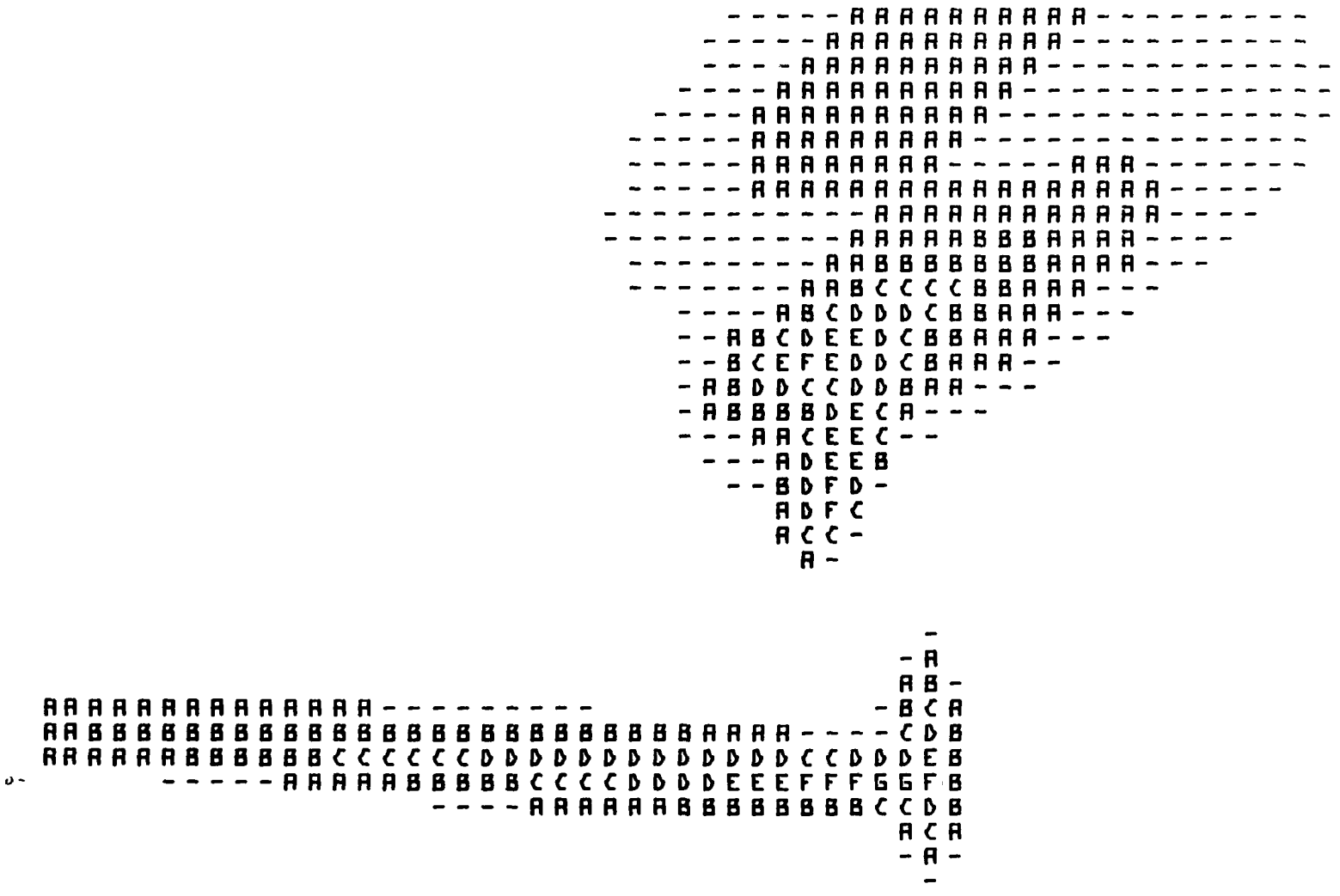


Figure 9. H+1 DOSE RATE FOR 3.4 MT WEAPON FOR USER MANUAL WINDS ON 5 MILE GRID WITH RANDOM SEED

Figure 10. H+1 DOSE RATE FOR 3.4 MT WEAPON FOR USER MANUAL WINDS ON 5 MILE GRID WITH RANDOM SEED

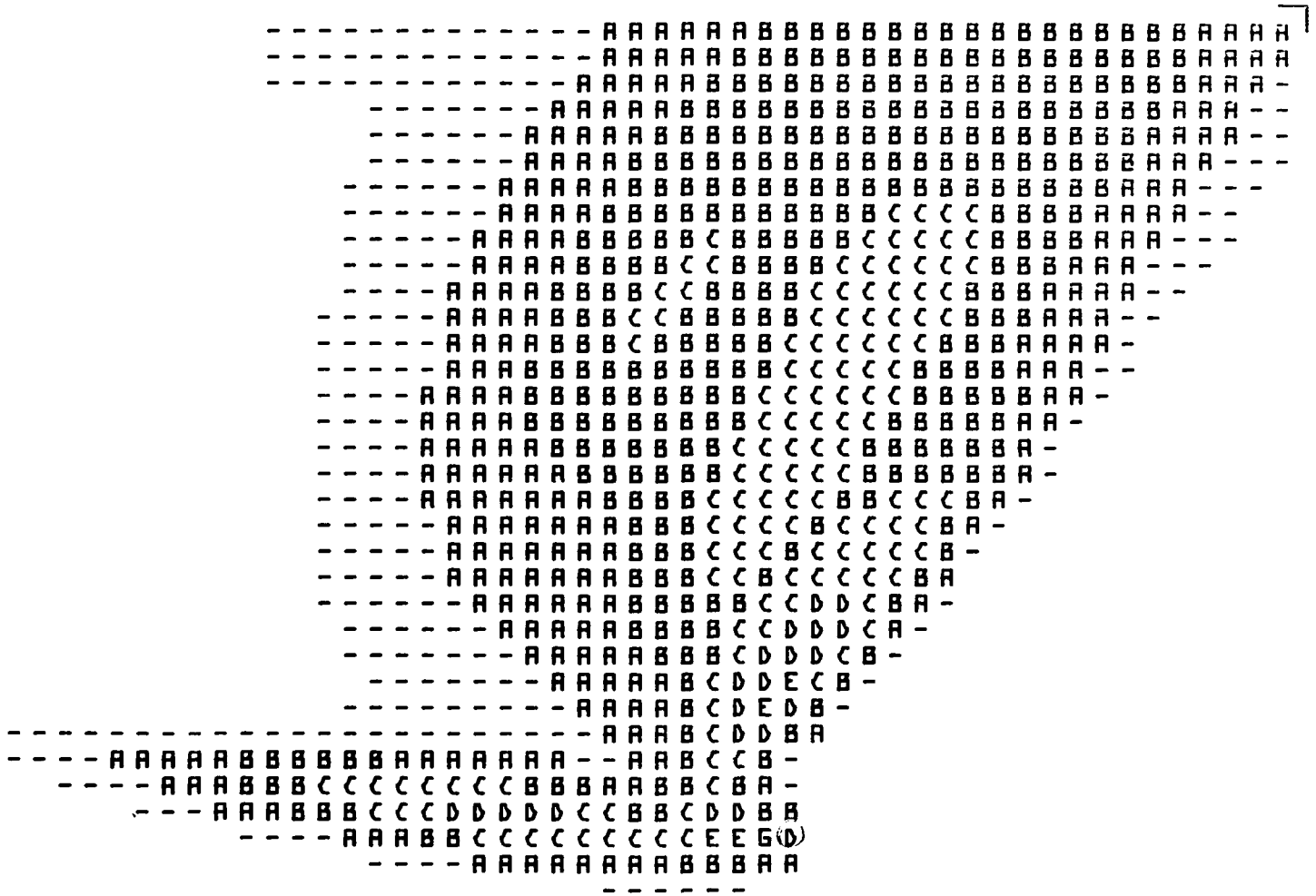


Figure 11. DOSE RATE FOR 3.4 MT WEAPON FOR USER MANUAL WINDS ON 5 MILE GRID WITH MIDRANGE DISTRIBUTION VALUES

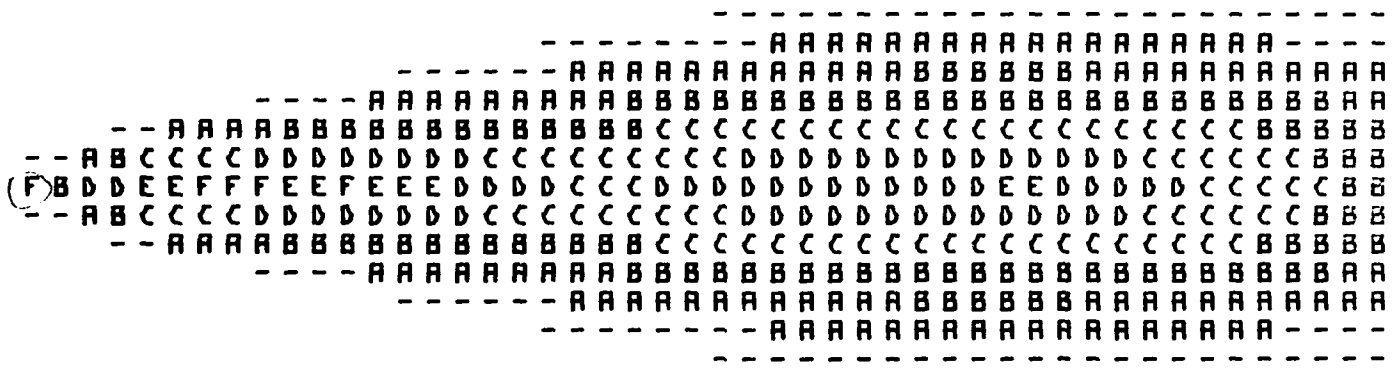


Figure 12. H+1 DOSE RATE FOR 1 MT WEAPON FOR CONSTANT 15 MPH WIND ON 5 MILE GRID WITH STANDARD SEED

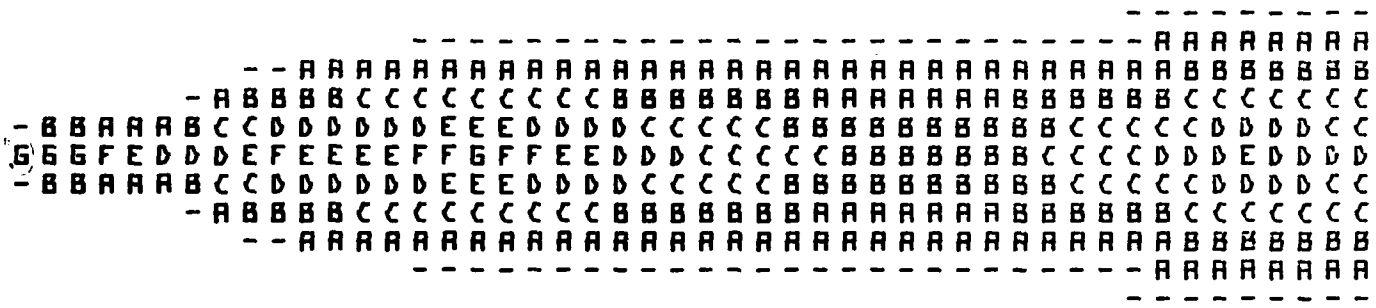


Figure 13. H+1 DOSE RATE FOR 1 MT WEAPON FOR CONSTANT 15 MPH WIND ON 5 MILE GRID WITH RANDOM SEED

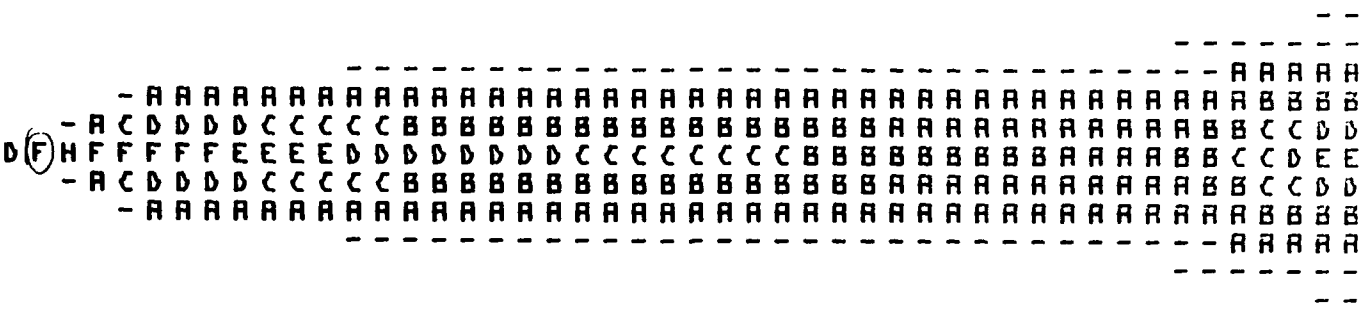


Figure 14. H+1 DOSE RATE FOR 1 MT WEAPON FOR CONSTANT 15 MPH WIND ON 5 MILE GRID WITH RANDOM SEED

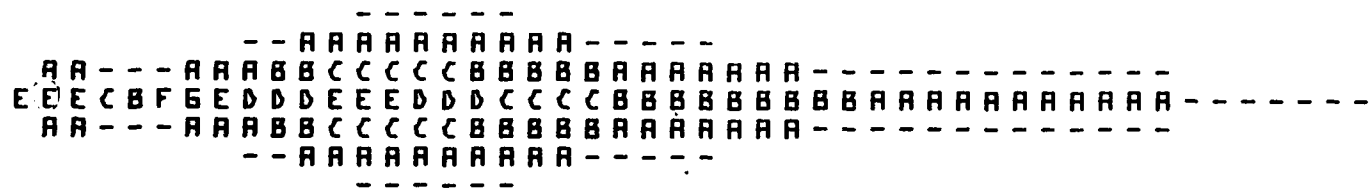


Figure 15. H+1 DOSE RATE FOR 1 MT WEAPON FOR CONSTANT 15 MPH WIND ON 5 MILE GRID WITH RANDOM SEED

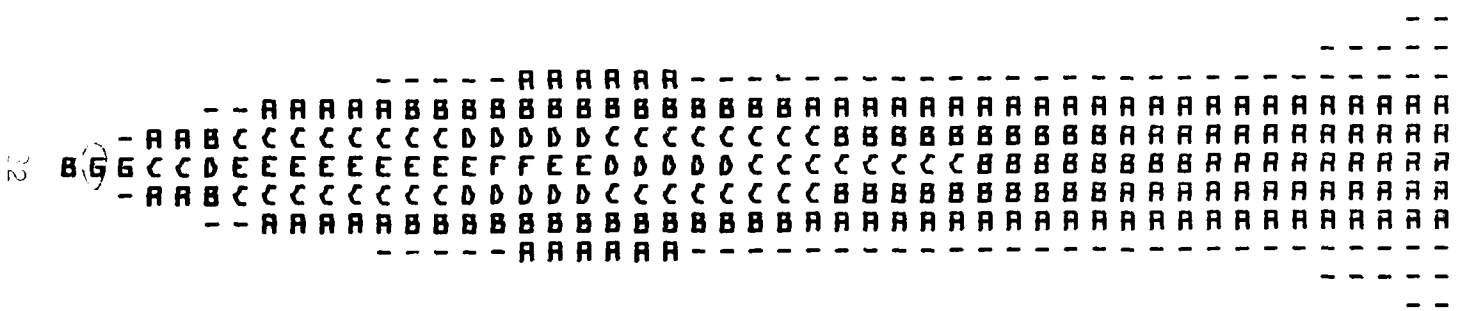


Figure 16. H+1 DOSE RATE FOR 1 MT WEAPON FOR CONSTANT 15 MPH WIND ON 5 MILE GRID WITH RANDOM SEED

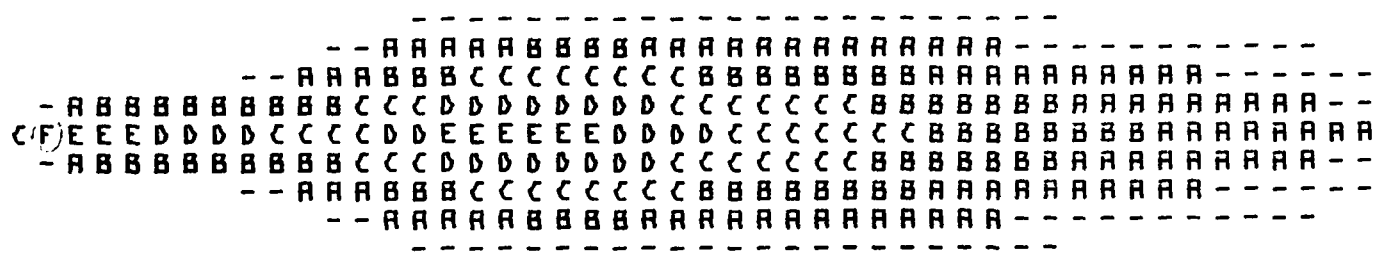
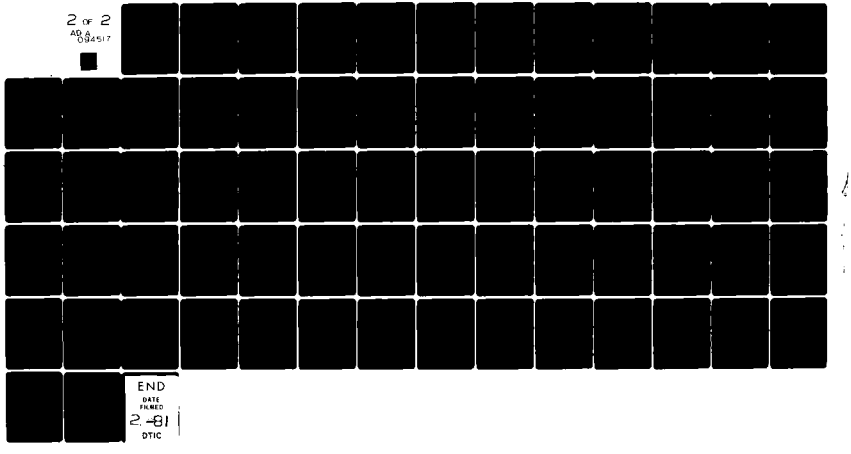


Figure 17. H+1 DOSE RATE FOR 1 MT WEAPON FOR CONSTANT 15 MPH WIND ON 5 MILE GRID WITH RANDOM SEED

AD-A094 517 INSTITUTE FOR DEFENSE ANALYSES ARLINGTON VA PROGRAM --ETC F/G 15/3
DEVELOPMENT OF CIVIL DEFENSE DAMAGE ASSESSMENT PROGRAMS.(U)
NOV 80 L A SCHMIDT DCPA01-77-C-0215
UNCLASSIFIED IDA-P-1526 IDA/HQ-80-22838 NL



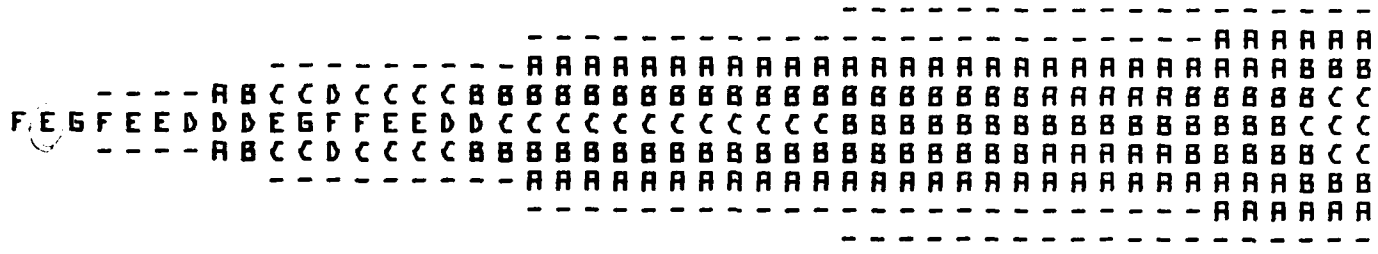


Figure 18. H+1 DOSE RATE FOR 1 MT WEAPON FOR CONSTANT 15 MPH WIND ON 5 MILE GRID WITH RANDOM SEED

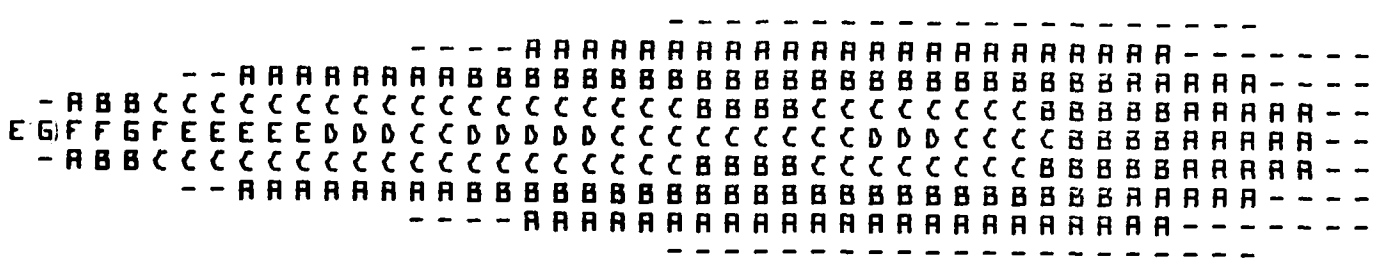
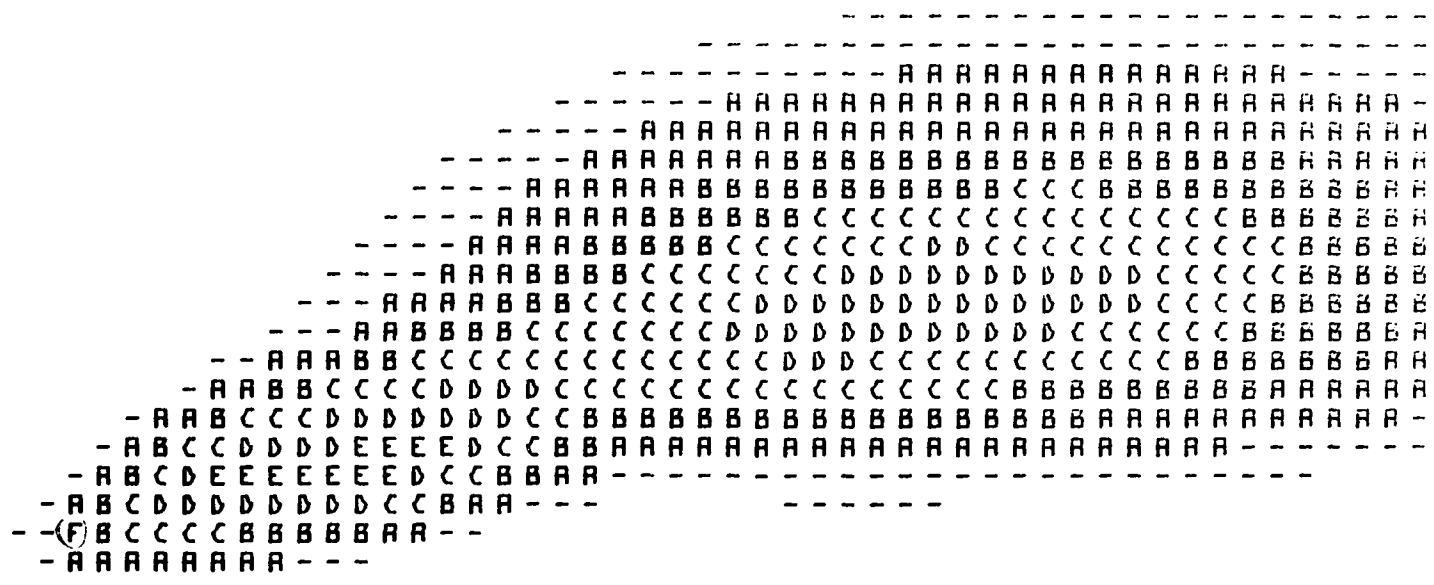


Figure 19. H+1 DOSE RATE FOR 1 MT WEAPON FOR CONSTANT 15 MPH WIND ON 5 MILE GRID WITH MIDRANGE DISTRIBUTION VALUES



Alt Kilofeet	V mph	θ deg
0	15	270
20	15	240
40	15	270
60	15	270
80	15	270
100	15	270

Figure 20. H+1 DOSE RATE FOR 1 MT WEAPON WITH 15 MPH WIND SLEWED AT 20 KILOFEET ON 5 MILE GRID WITH STANDARD SEED

Alt Kilofeet	V mph	θ deg
0	15	270
20	15	240
40	15	240
60	15	270
80	15	270
100	15	270

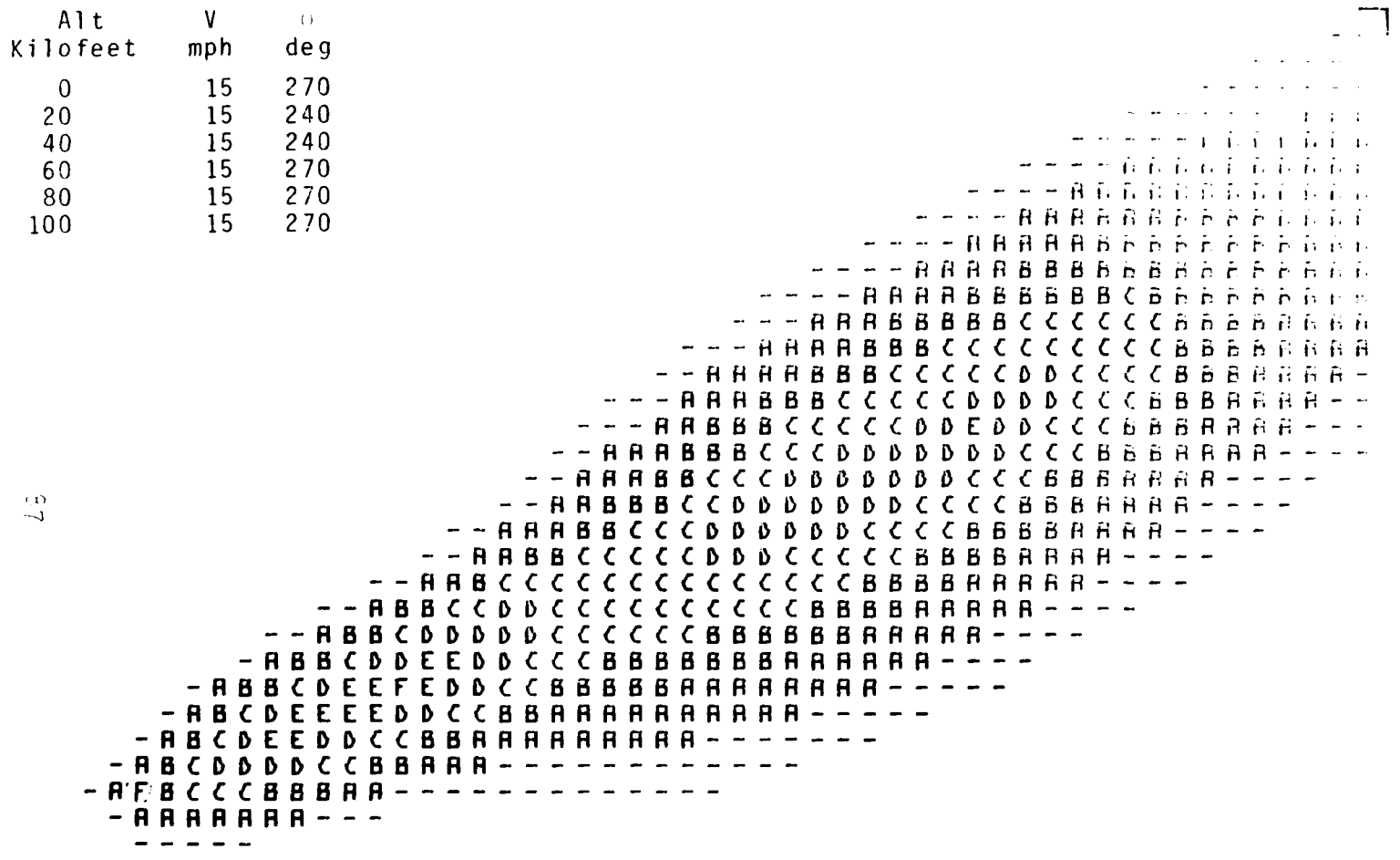


Figure 21. H+1 DOSE RATE FOR 1 MT WEAPON WITH 15 MPH WIND SLEWED AT 20 AND 40 KILOFEET ON 5 MILE GRID WITH STANDARD SEED

Alt Kilofeet	V mph	θ deg
0	15	300
20	15	240
40	15	240
60	15	180
80	15	180
100	15	180

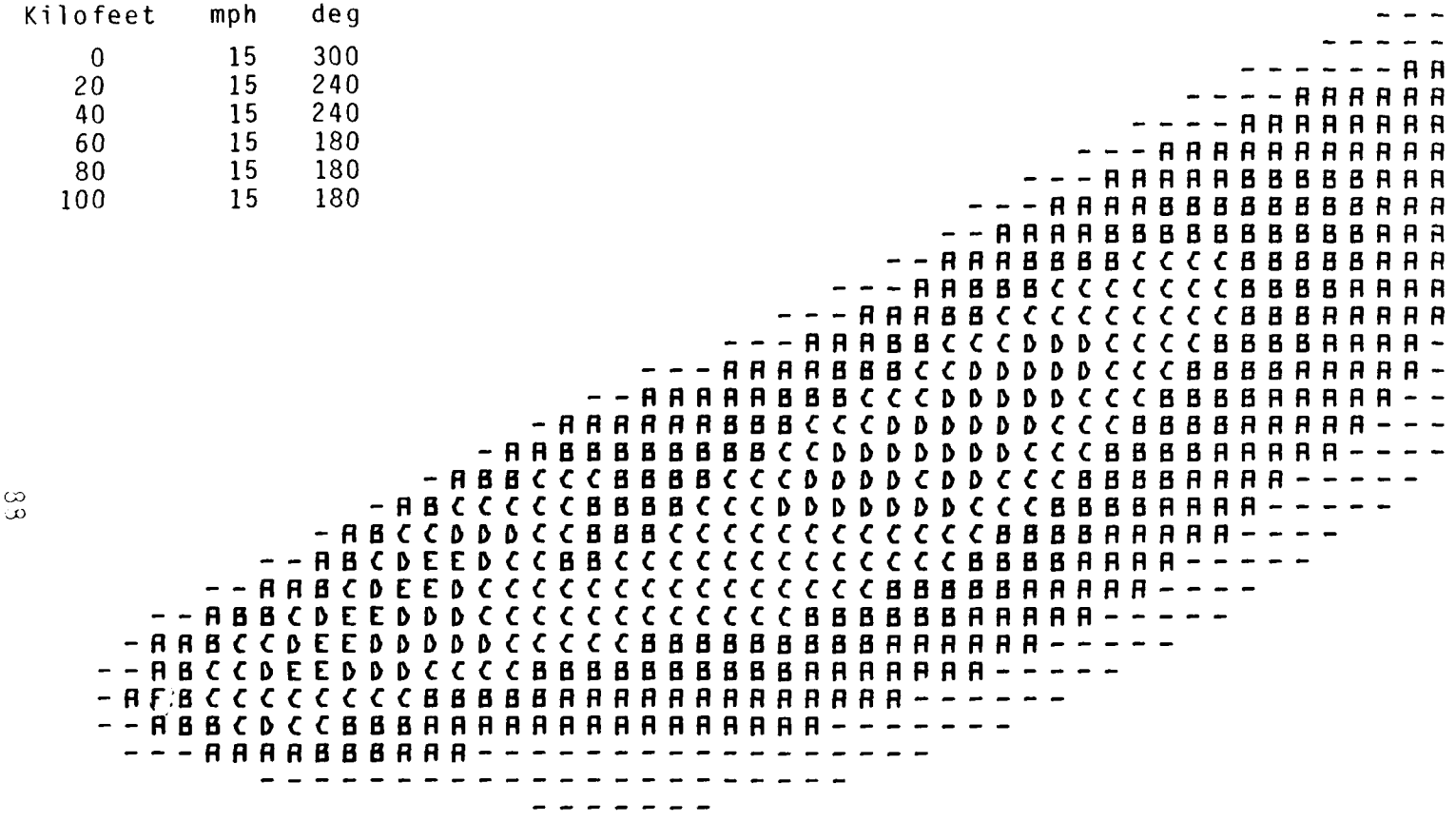


Figure 22. H+1 DOSE RATE FOR 1 MT WEAPON WITH 15 MPH WIND WITH GROUND WIND SLEWED ON 5 MILE GRID WITH STANDARD SEED

Alt Kilofeet	V mph	θ deg
0	15	300
20	15	270
40	15	210
60	15	180
80	15	180
100	15	180

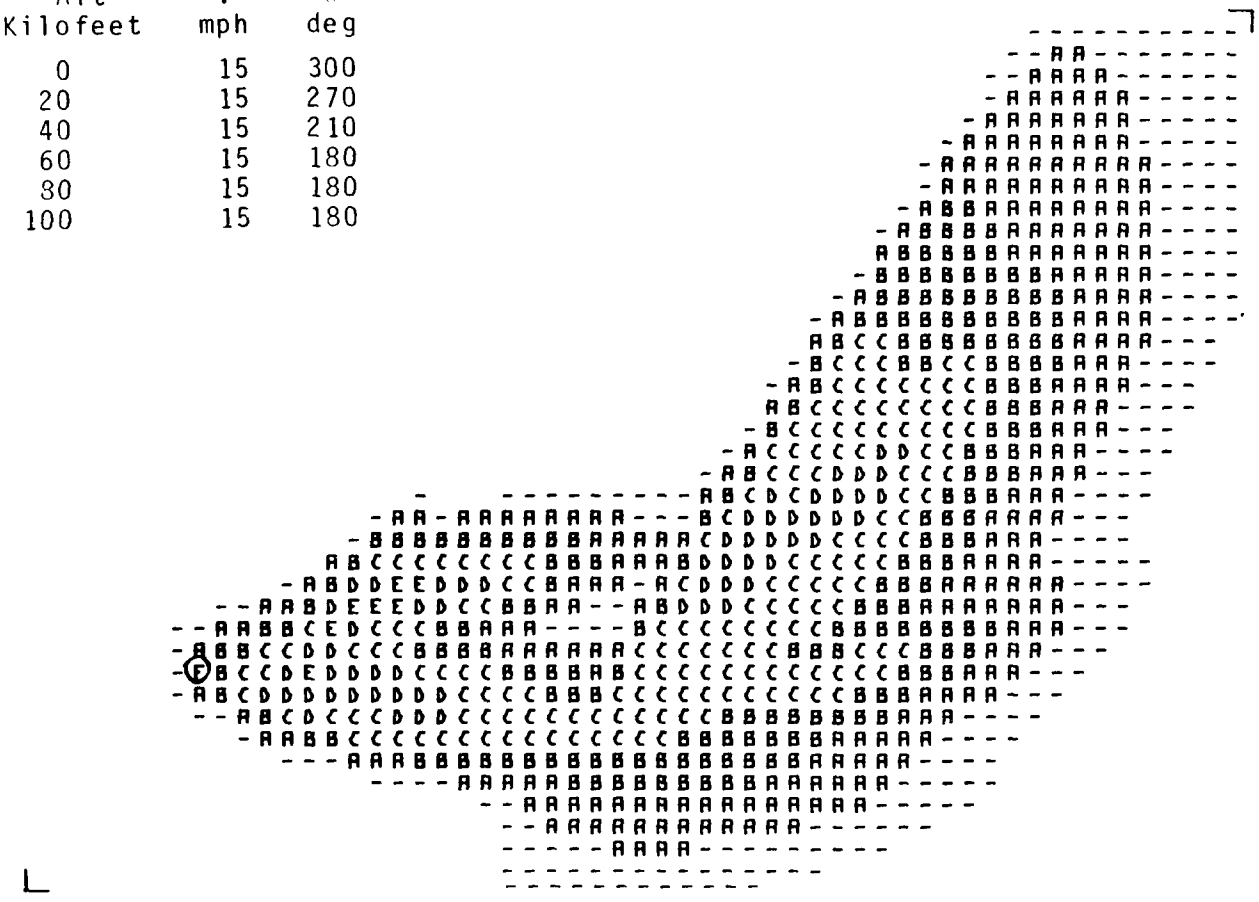
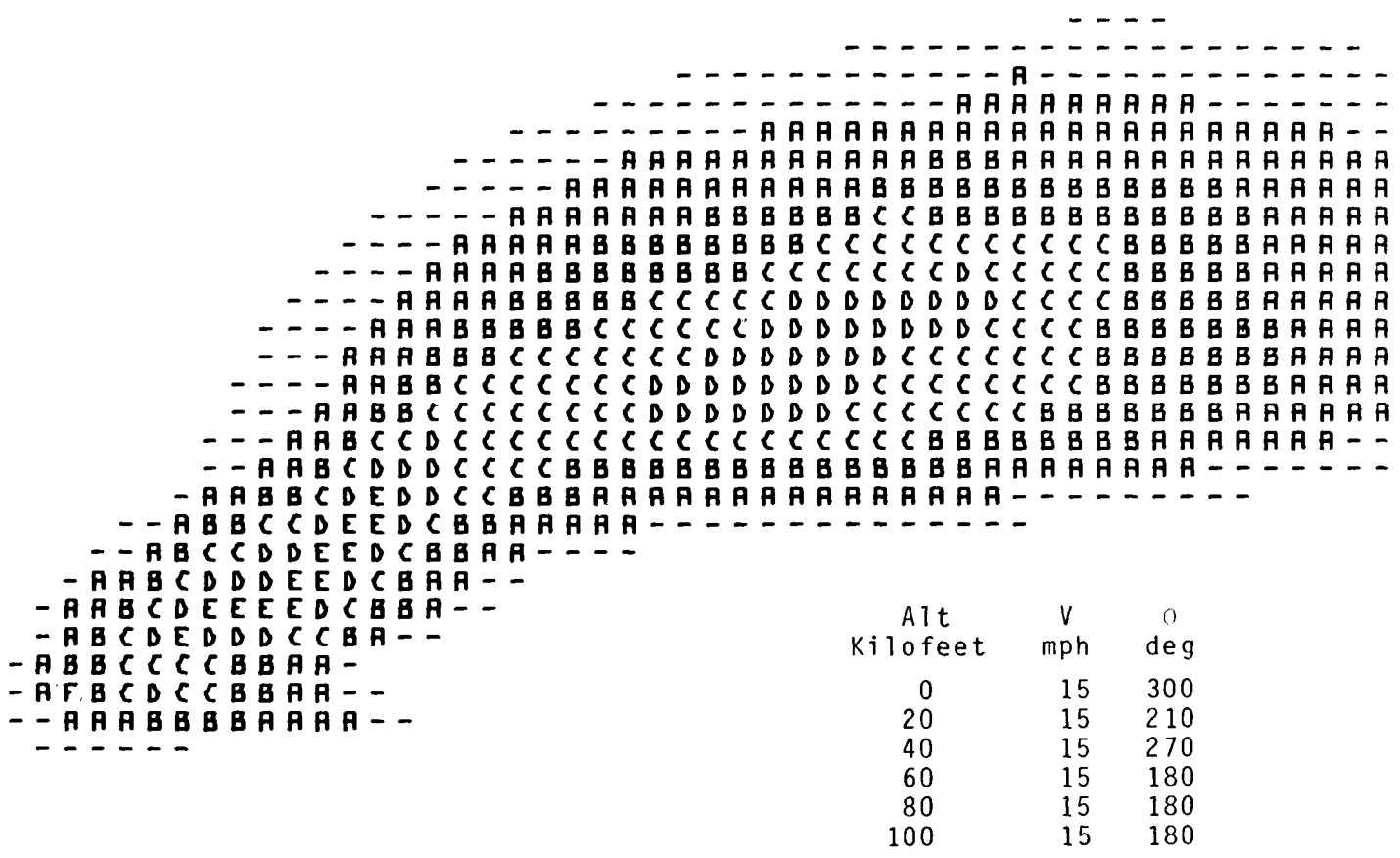


Figure 23. H+1 DOSE RATE FOR 1 MT WEAPON WITH 15 MPH WIND WITH 40 KILOFOOT WIND NORTH OF 20 KILOFOOT WIND ON 5 MILE GRID WITH STANDARD SEED



Alt Kilofeet	V mph	O deg
0	15	300
20	15	210
40	15	270
60	15	180
80	15	180
100	15	180

Figure 24. H+1 DOSE RATE FOR 1 MT WEAPON WITH 15 MPH WIND WITH 20 KILOFOOT WIND NORTH OF 40 KILOFOOT WIND ON 5 MILE GRID WITH STANDARD SEED

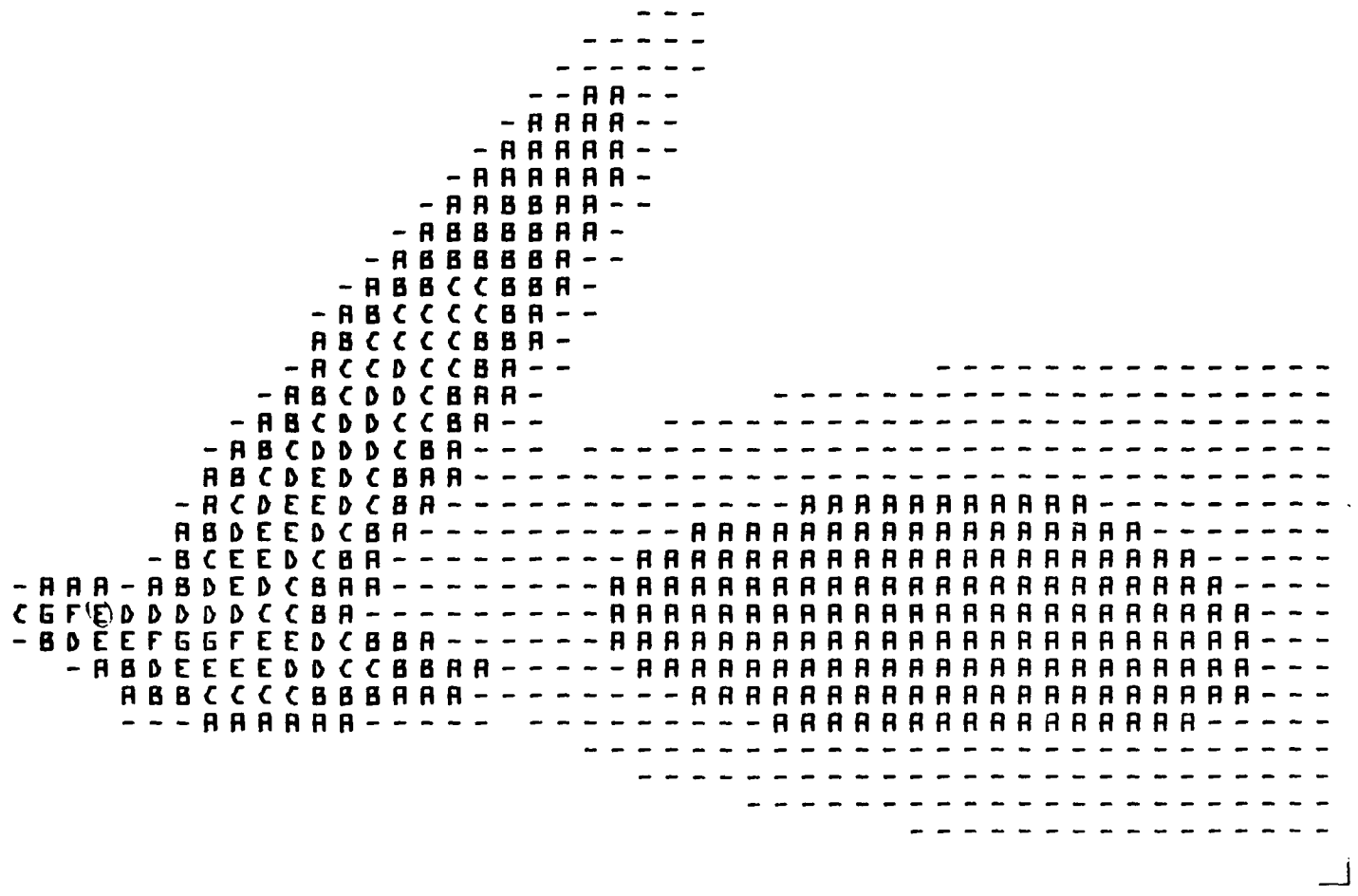


Figure 25. H+1 DOSE RATE FOR 1 MT WEAPON WITH 15 MPH WIND WITH 20 KILOFOOT WIND NORTH OF 40 KILOFOOT WIND ON 5 MILE GRID WITH RANDOM SEED

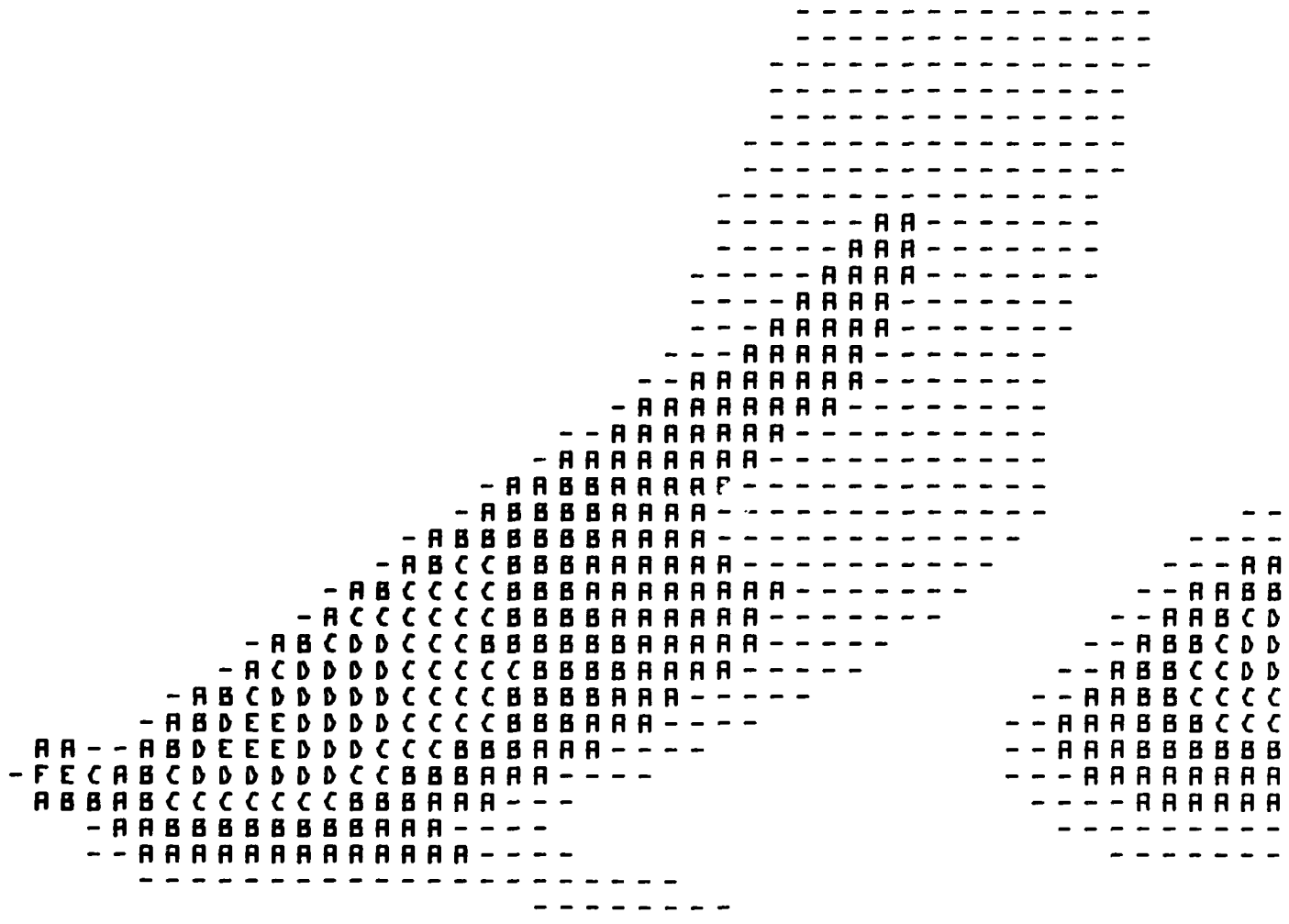


Figure 26. H+1 DOSE RATE FOR 1 MT WEAPON WITH 15 MPH WIND WITH 20 KILOFOOT WIND NORTH OF 40 KILOFOOT WIND ON 5 MILE GRID WITH RANDOM SEED

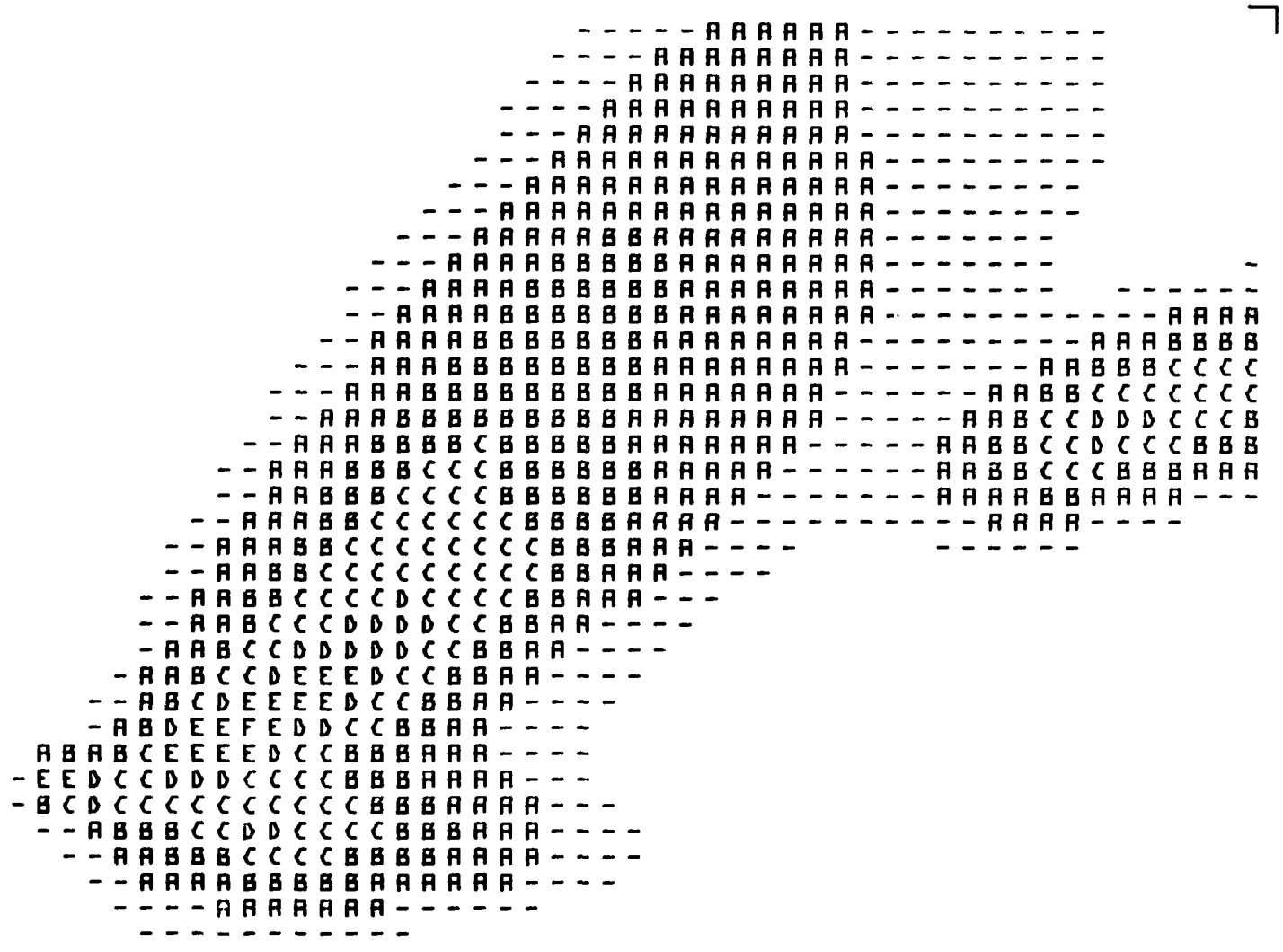


Figure 27. H+1 DOSE RATE FOR 1 MT WEAPON WITH 15 MPH WIND WITH 20 KILOFOOT WIND NORTH OF 40 KILOFOOT WIND ON 5 MILE GRID WITH RANDOM SEED

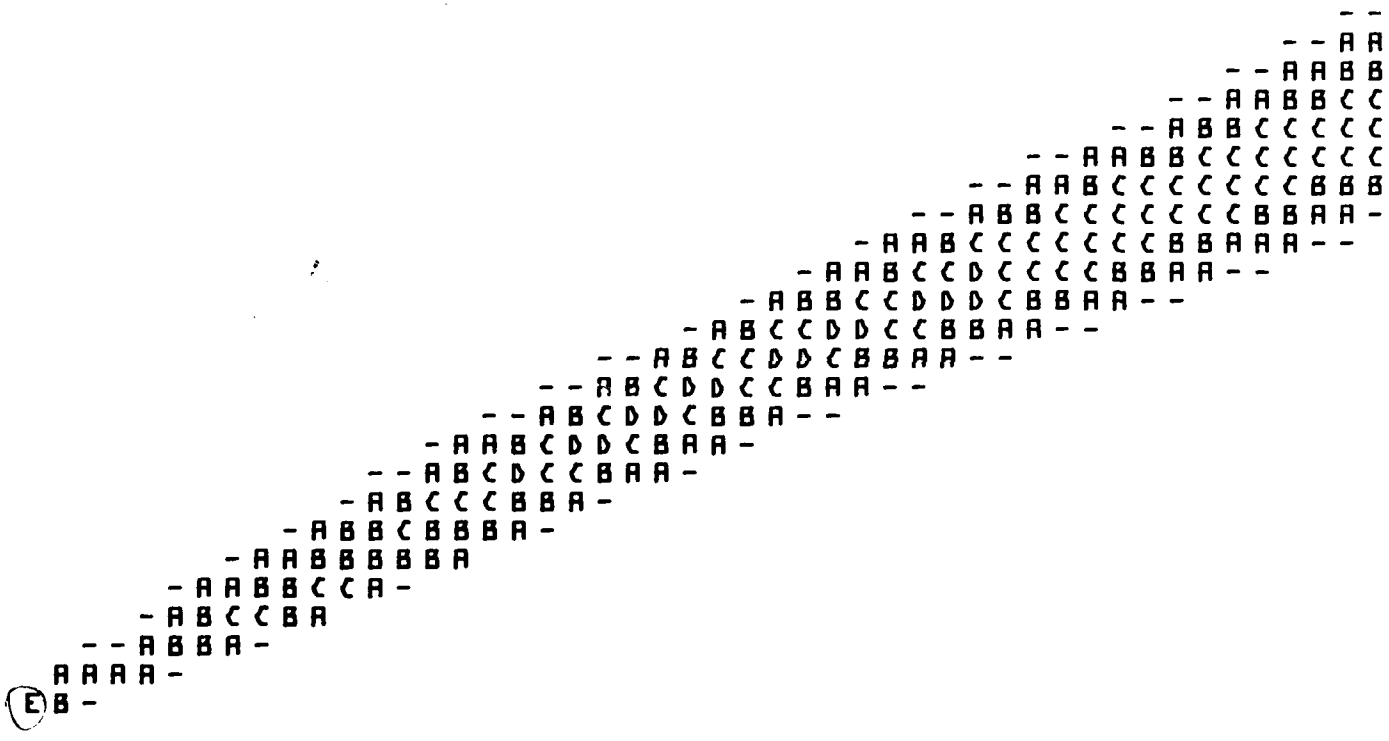


Figure 28. H+1 DOSE RATE FOR 1 MT WEAPON WITH WASHINGTON D.C. OCTOBER WIND ON 5 MILE GRID WITH STANDARD SEED

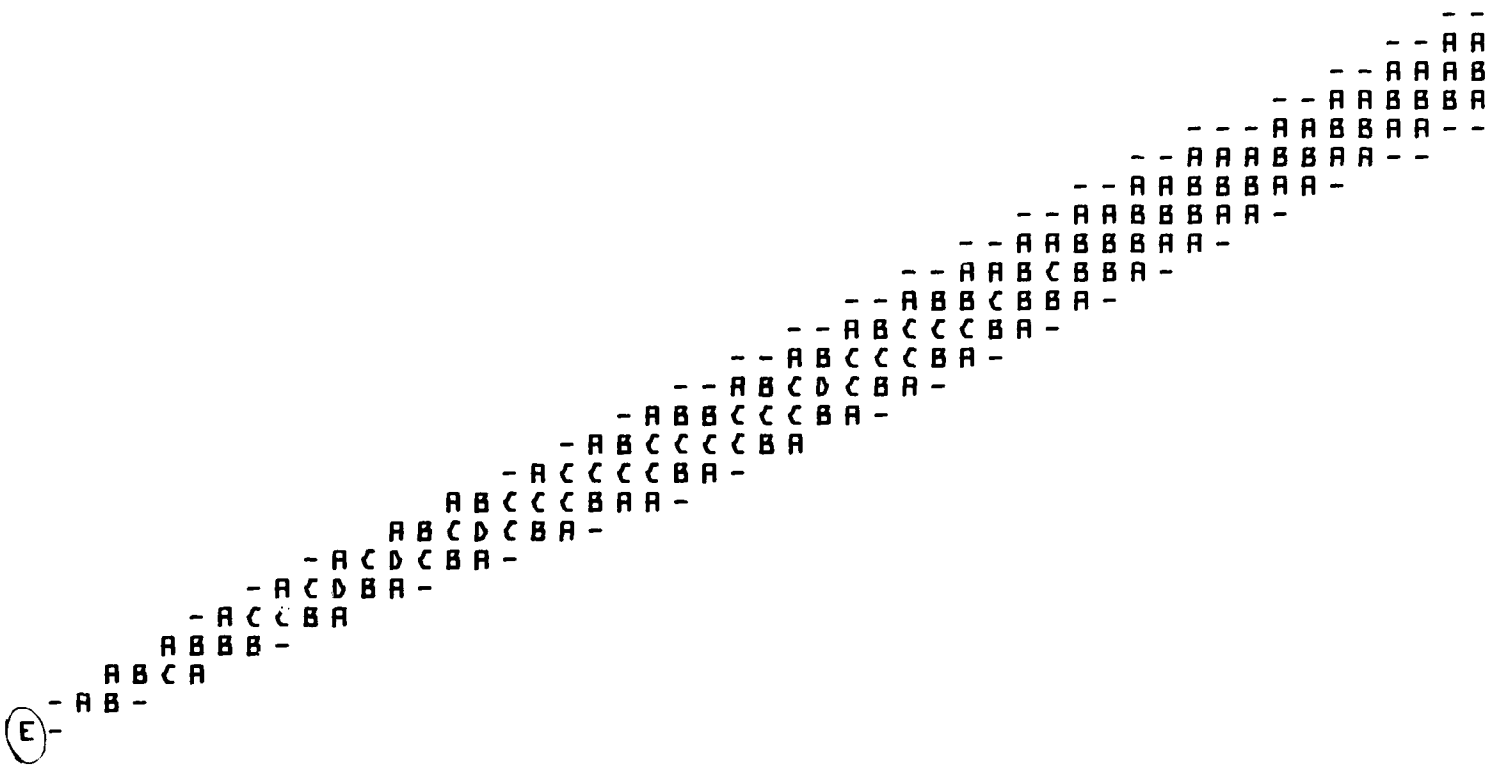


Figure 29. H+1 DOSE RATE FOR 1 MT WEAPON WITH WASHINGTON D.C. OCTOBER WIND ON 10 MILE GRID WITH STANDARD SEED

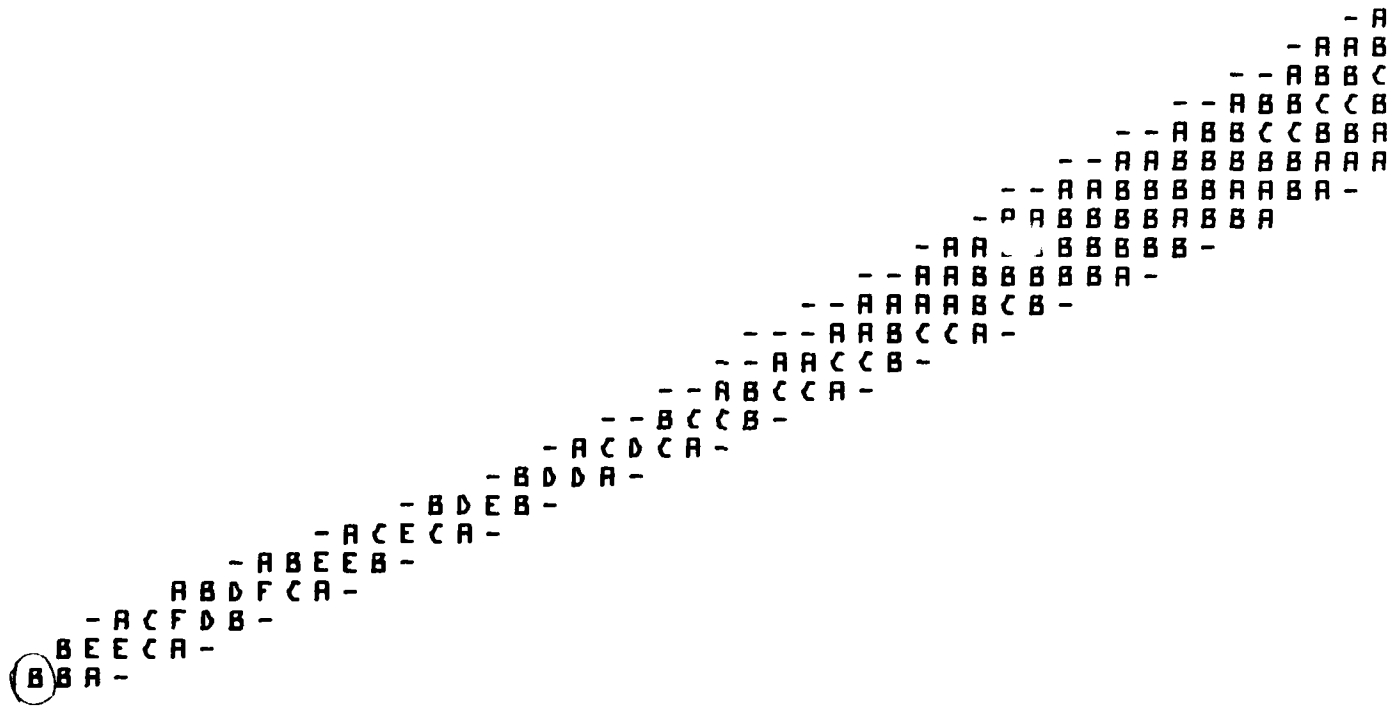


Figure 30. H+1 DOSE RATE FOR 1 MT WEAPON WITH WASHINGTON D.C. OCTOBER WIND ON 5 MILE GRID WITH RANDOM SEED

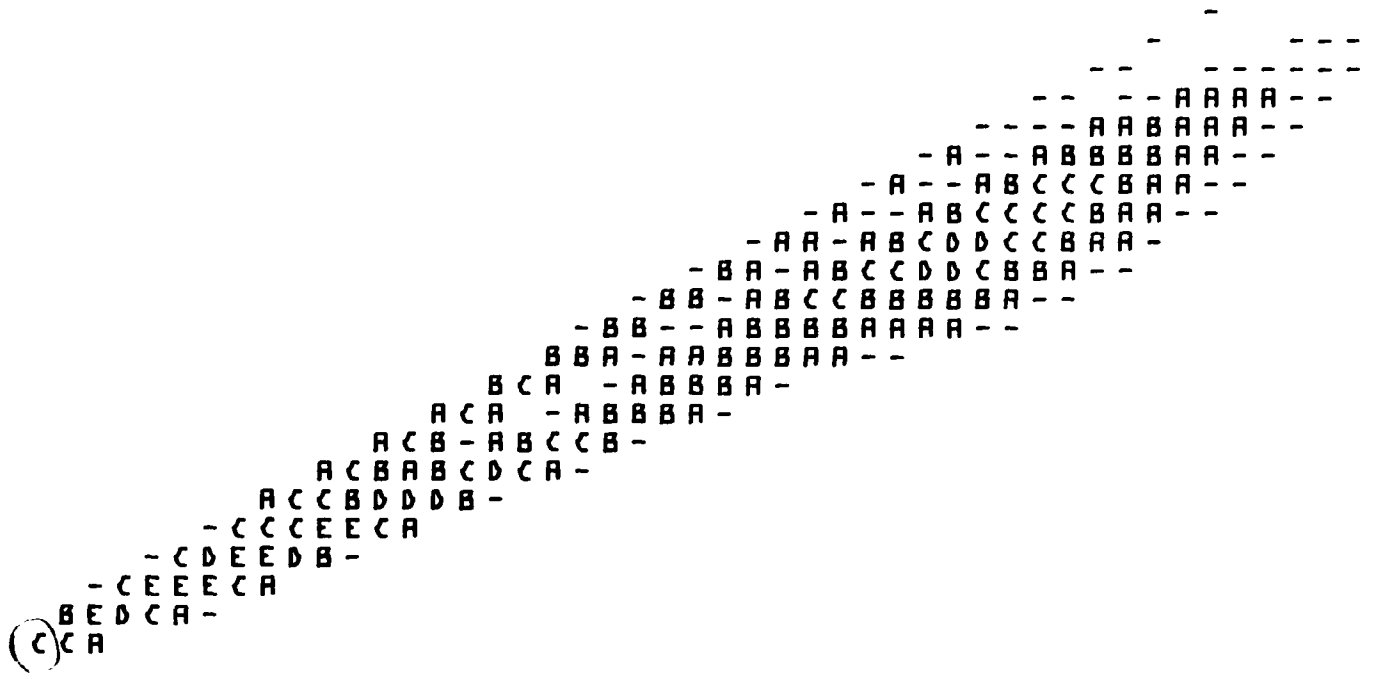


Figure 31. H+1 DOSE RATE FOR 1 MT WEAPON WITH WASHINGTON D.C. OCTOBER WIND ON 5 MILE GRID WITH RANDOM SEED

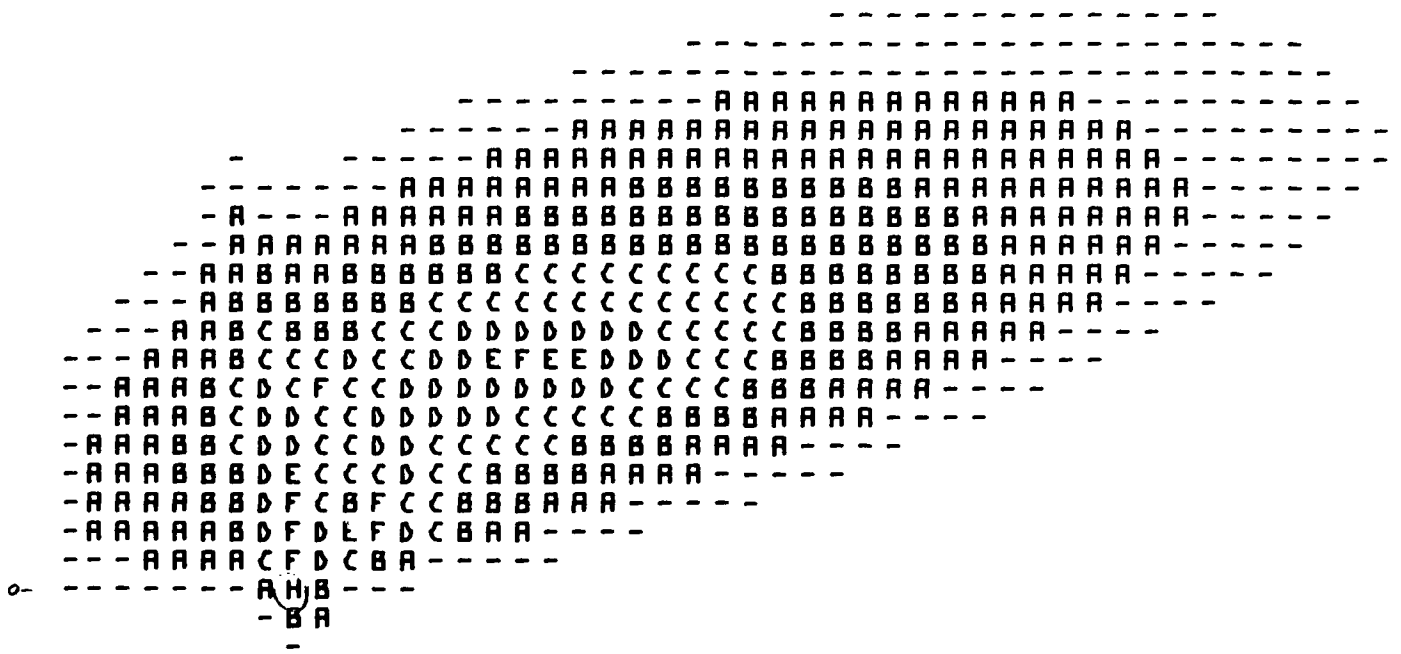


Figure 32. H+1 DOSE RATE FOR 1 MT WEAPON WITH STOCKTON, CALIF. OCTOBER WIND ON 5 MILE GRID WITH STANDARD SEED

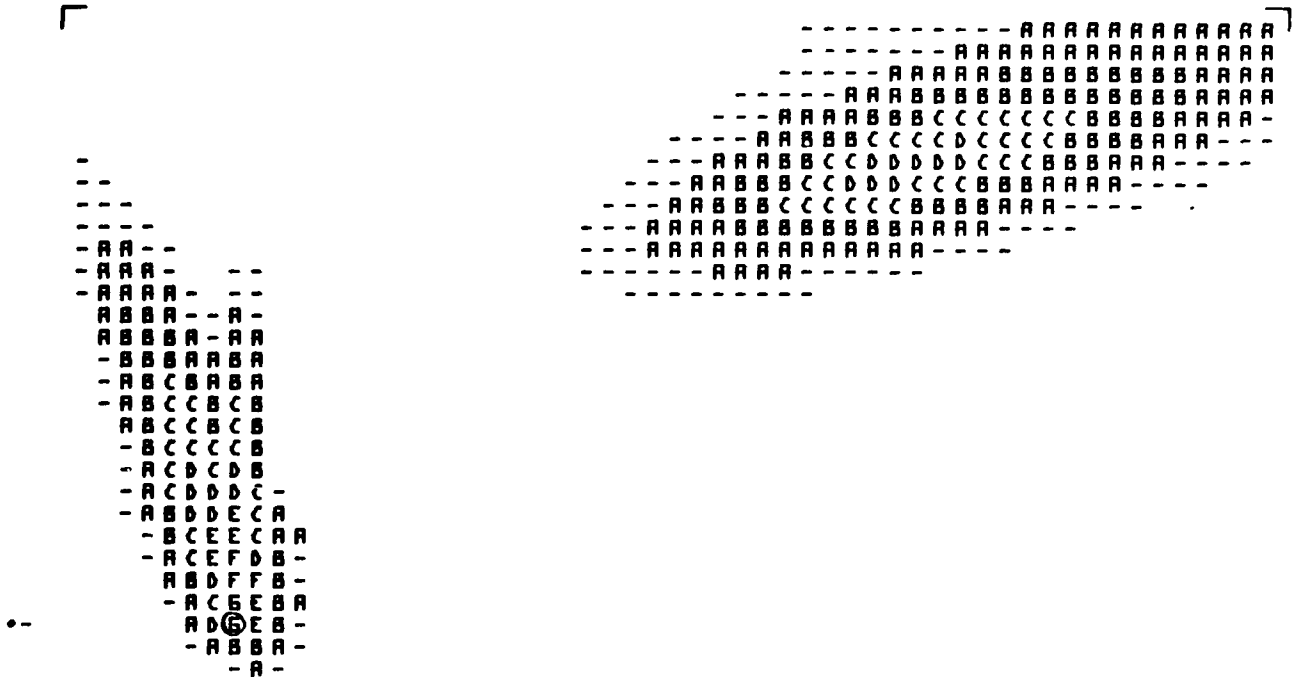


Figure 33. H+1 DOSE RATE FOR 1 MT WEAPON WITH STOCKTON, CALIF. OCTOBER WIND ON 5 MILE GRID WITH RANDOM SEED

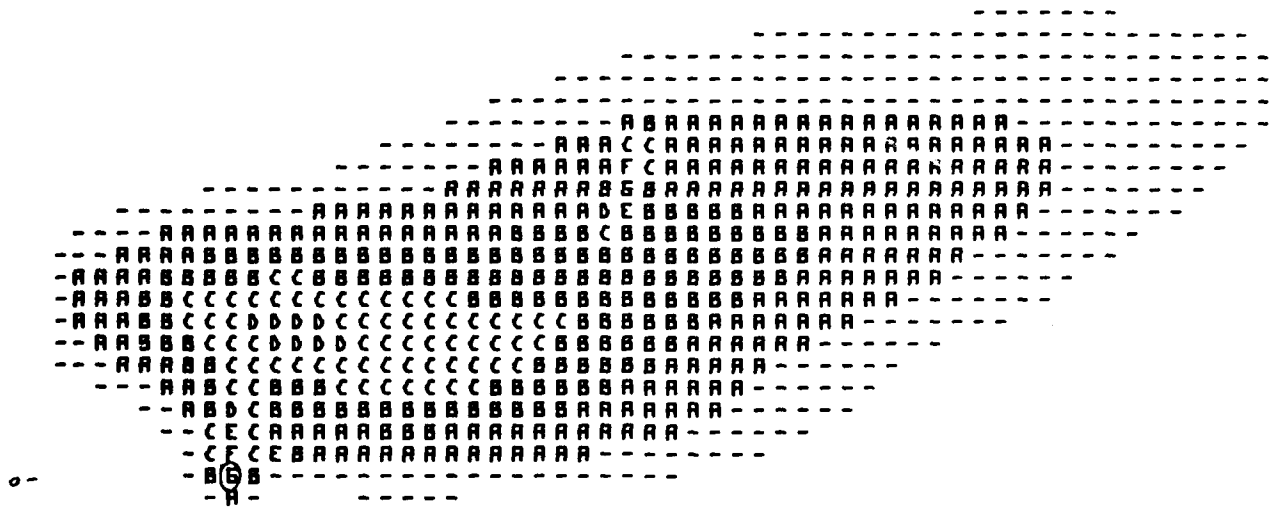


Figure 34. H+1 DOSE RATE FOR 1 MT WEAPON WITH STOCKTON, CALIF. OCTOBER WIND ON 5 MILE GRID WITH RANDOM SEED

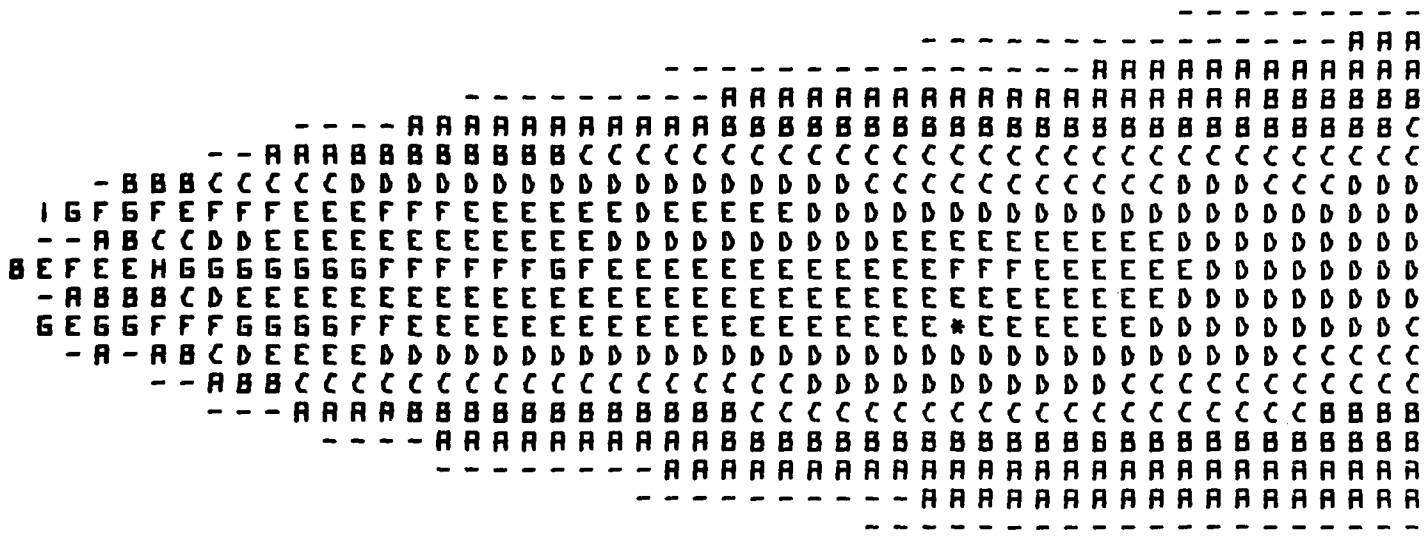


Figure 35. H+1 DOSE RATE FOR SEVEN 1 MT WEAPONS IN 20 MILE HEXAGON WITH 15 MPH CONSTANT WIND ON 5 MILE GRID WITH STANDARD SEED

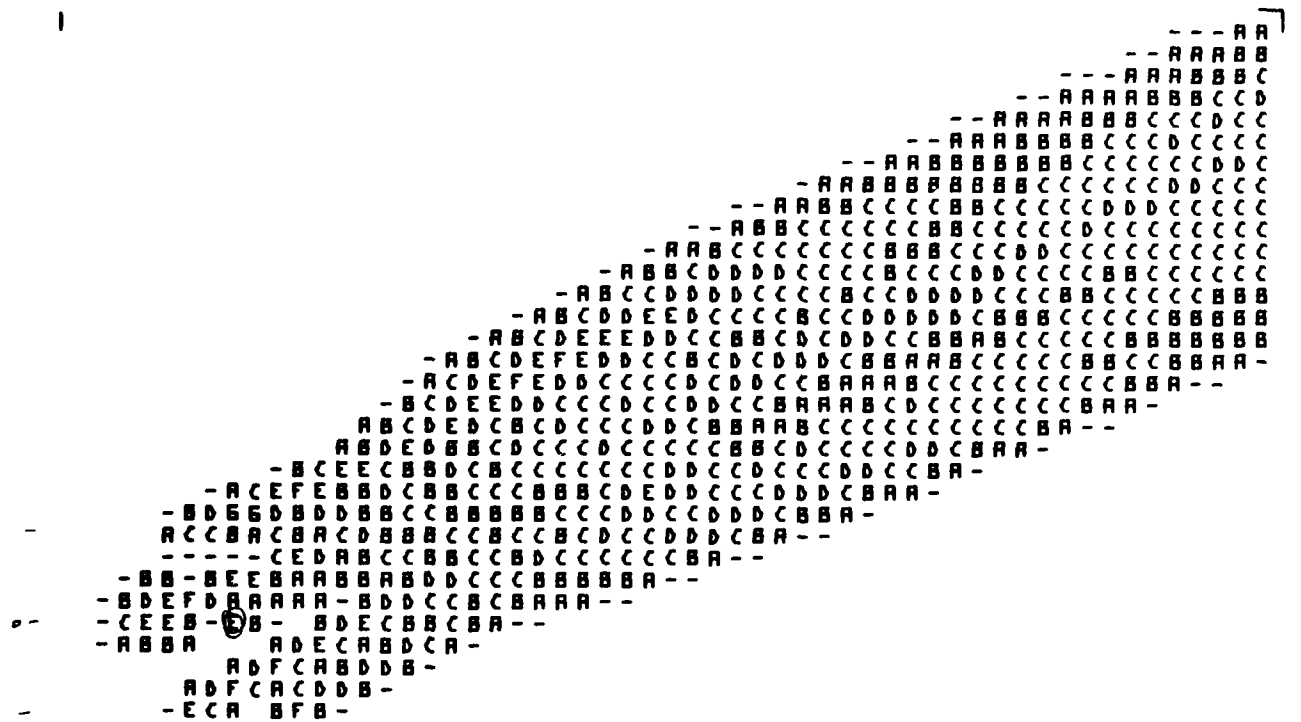


Figure 36. H+1 DOSE RATE FOR SEVEN 1 MT WEAPONS IN 40 MILE HEXAGON WITH WASHINGTON, D.C. OCTOBER WINDS ON 5 MILE GRID WITH STANDARD SEED

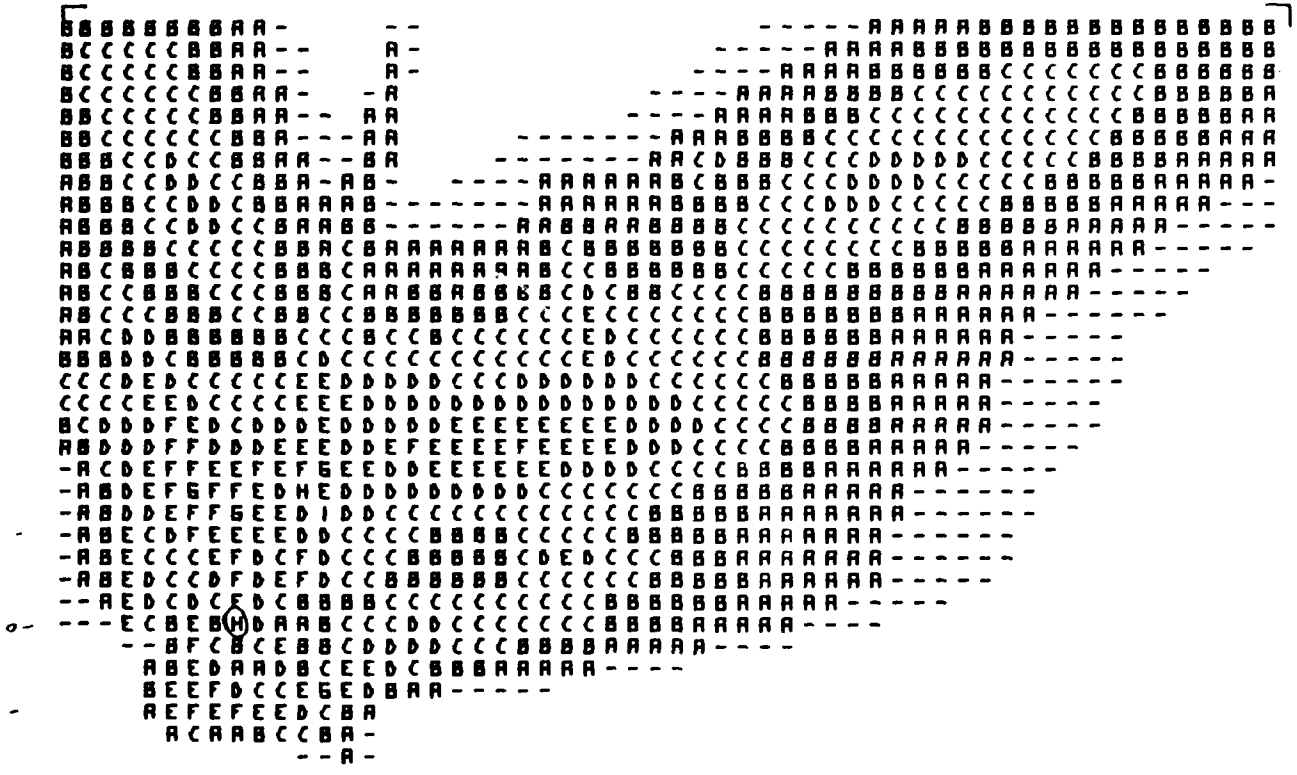


Figure 37. H+1 DOSE RATE FOR SEVEN 1 MT WEAPONS IN 40 MILE HEXAGON WITH STOCKTON, CALIFORNIA WINDS ON 5 MILE GRID WITH STANDARD SEED

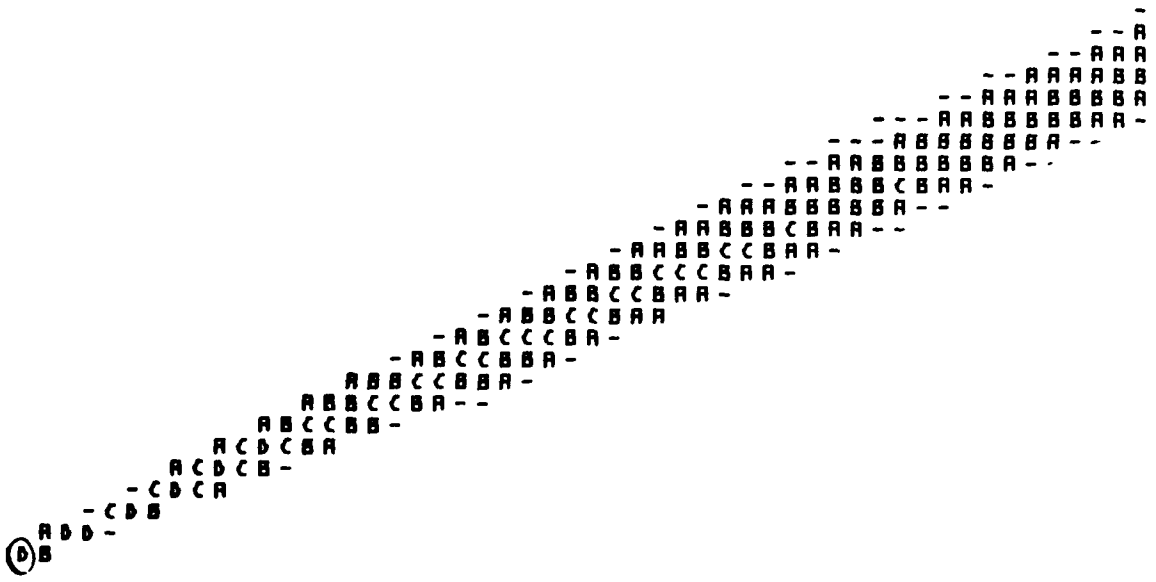


Figure 38. H+1 DOSE RATE FROM AVERAGE OF 50 COLLOCATED WEAPONS WITH WASHINGTON, D.C. OCTOBER WINDS ON 5 MILE GRID WITH RANDOM SEED

Figure 39. H+1 DOSE RATE FROM AVERAGE OF 50 COLLOCATED WEAPONS WITH STOCKTON, CALIFORNIA WINDS ON 5 MILE GRID WITH RANDOM SEED

E. MODIFICATIONS TO ORIGINAL CODE FOR MILLER-S MODEL

This section describes modifications made to the original MILLER-S computer program. The model was developed by Dr. Carl Miller under DCPA contract DAHC20-71-C-0273 (Work Unit 3119F) to the Dikewood Corporation. It is documented in a series of volumes--"The Analysis and Correlation of Fallout Pattern Data" [Ref. 9]. Part III is the "Computer Program Users Instructions." It contains a listing of the computer program, a sample problem, and output from this problem. References here to equations and algorithms defining the model will refer to Part II, "Derivation of Statistical Fallout System." In this report the total algorithm is divided into a series of 40 steps which are sequentially performed. This description of modifications will refer to sections and steps in this report.

The FEMA Computer Center had a copy of the program which was written for the CDC 3600 computer. The first step was to put the program on the Univac 1100/10 system and to convert the program to be syntactically compatible with the Univac system. Fortunately this conversion involved no changes which were directly related to the computation schemes except to change the nature of the calls to the random number generating routine. It was impossible to compare the calculational results with those in Part III of the Miller report since the change in the random number generating routine resulted in a different set of random numbers being generated even though the same seed was used and, therefore, in a different set of answers.

On the code listing received at the DCPA Computer Center, two corrections were written in by hand. The first, in step 31, sets the value of Q(I)=1 if the absolute value of shear angle α is less than 0.001. The second, in step 34, changes its original calculation of k_{34} from

$$k_{34} = \frac{2k_{30} \cdot k_4}{1+k_{30}}$$

to

$$k_{34} = \frac{2k_3 \cdot k_4}{k_3 + k_4}$$

The next change occurred in step 27 at statement number 485 where a test is made for k_m less than a value PDENOM, where

$$\text{PDENOM} = 1/(\text{AVGVEL} \cos \alpha \sin \alpha).$$

For values of α greater than 90°, PDENOM becomes negative and an indefinite duration loop can occasionally be entered for unfortunate choices of random numbers. The change was to use the absolute value of PDENOM in the test to avoid this possibility. A similar change to avoid the same problem was made in step 31.

In order to achieve greater flexibility of use, the program was divided into subroutines. Steps 17, 30, 37, 39 and 40 are repeated for each monitor point at which a dose is to be calculated. They are put into a separate subroutine, XYDOSE. This is called for each new monitor point where each of these steps is executed once. The remainder of the steps are executed once for each weapon and are put in subroutine SUBCLD which is called for each weapon. The input of data was placed in a separate subroutine. The main program then becomes simply a caller of subroutines and can be readily changed to meet a variety of ways of exercising the model. Two methods are implemented, one to have a single weapon with monitor points in a rectangular grid, and the other to have multiple weapons of the same yield with monitor points on a grid. The output of the subroutine program was carefully checked against the

output obtained before dividing into subroutines to ensure the calculational scheme was the same. Identical results were obtained from the two programs.

The report *Fallout Modifications Due to Unusual Burst Conditions*, Carl Miller, DCPA Work Unit 32231, December 15, 1978 [Ref. 10], contains several modifications to the original code. The first modification is in step 3. In both cases for $I > 4$, v_f is computed by

$$v_f = v_{f0}\exp(-0.0029\lambda) .$$

After this calculation the following is inserted:

If $W < 78$ bypass this insert.

otherwise

$$v_f = v_{f0}\left(\frac{W}{75}\right)^{-0.29} .$$

If midrange values are used, go to the end of this insert, otherwise compute $v_{max} = 155W^{-0.5}$. If $0.1 < v_{max}$ go to the end of this insert, otherwise draw a new random v_{f0} and go to the beginning of this insert.

The next modification is in step 23 in the method of computing K_{RL}. K_{RL} is now computed by

$$K_{RL} = \begin{cases} \frac{v_f}{v_0} K_{RL}^2 W^{-0.29} & W < 78 \\ \\ \frac{v_f}{v_0} K_{RL}^2 & W \geq 78 \end{cases}$$

In addition, the new values for the minimum, maximum and midrange of the K_{RL}^2 in this report were placed in the program.

A new method for the calculation of the dose at a point in step 36 is given in this report. This method was coded and placed in the code. The report has some hand calculations for dose at a few different distances for a 1 MT weapon with a constant 15 mph wind. The results from the computer code were close enough to the hand calculation to verify the algorithm used.

In the process of comparing results, an error in coordinate transformations was discovered in the program. The coding for CAPX was CAPX(I) = (Y-YCZERO(I)).cos DPH(I) - (X-XCZERO(I)). sin DPH(I). The minus sign between the two terms in this equation was changed to a plus sign.

The next change increased the model output by a factor of $(4/3)^2$ to account for ground roughness and instrument calibration factors. The original predicted dose would be comparable to "as measured" doses while the corrected dose is comparable to the doses given by the fallout prediction models.

The next modification introduced two additional means for handling the "k-factor" in the model. In the original model, the k-factor could vary from a minimum of 166 to maximum of 2186, with a mean value of 1484. A new input variable KFACSW was defined. If this variable has a value of 0, the original model calculation is used. A NAS report recommends a k-factor value of 1930. If KFACSW is 1, the originally selected activity in each subcloud is changed so that their ratios are the same, but the weapon k-factor is always 1930. If KFACSW is 2, the activity in each subcloud is increased by its ratio 1930/1484 so that the average weapon k-factor is 1930.

An option was introduced to compute the biological dose if the new input parameter KBIOSW is 1. The first step in computing the biological dose is in step 12, to save the time of arrival on the ground of t_a particles from each subcloud.

A new step, 39-1/2, is introduced which is performed for each weapon when KBIDNW≠0. From a modified Eq. 67 of the model documentation, a cloud stabilization time is computed by

$$t_s = 0.17W^{-.1} \text{ hrs} .$$

For I = 1,4 the cloud rise time is based on a formula from the MILLER II model in *Computer Implementation of the OCD Fallout Model*, ARS Report 66-44, OCD Task 3117C, 6/30/67, namely:

$$t_r = \ln(C_1/(C_2-h_{xi}))$$

where $C_1 = 18.W^{.116}$

$$C_2 = 21.56/W^{.116}$$

h_{xi} = is the initial selected height of the ith subcloud

We then take $t_r = \min(t_r, t_s)$.

For I = 5 to 10 we set

$$t_r = t_s .$$

t_r is added to the time of fall, t_f, to get the earliest time of arrival, t_e, of the fallout, i.e:

$$t_e = t_f + t_r .$$

A radius of earliest arrival, r_e, is computed by

$$r_e = \log (I_0/I)/K_{RL},$$

and downwind distance by

$$X_e = \log (I_0/I)/l_{RL}.$$

In these two equations the logarithm (I_0/I) is set equal to 3.

For each monitor point, a step 40 1/2 is added to the subroutine XYDOSE which computes the biological dose. This is done by assuming a linear arrival of fallout between fallout arrival and cessation and integrating the fallout arrival

times at a $t^{-1.2}$ decay rate. To this is added the biological dose after the time of fallout deposition cessation using a formula for the ratio of biological to H+1 dose rate for deposited fallout starting at a time t_c, assuming a 90 percent biologically repairable dose with a repair constant of three days. The formula is from [Ref. 7].

A center of the arriving dose is computed by

$$X_e = \begin{cases} X - \sqrt{r_e^2 - Y^2} & |Y| < R_e(I) \\ X & |Y| \geq R_e(I), \end{cases}$$

where X and Y are coordinates relative to the subcloud axis. A time of fallout arrival is computed by

$$t_a = \begin{cases} t_e + (X_e - X_{eo})/V_0 & X_e \geq X_{eo} \\ t_e & X_e \geq X_{eo} . \end{cases}$$

A time of fallout cessation is computed by

$$t_c = t_a + \frac{2r_e}{V_0} .$$

During the time of fallout buildup, the accrued dose is given by

$$D_1 = FII(I)\ [1.25(t_c^{.8} - t_a^{.8}) + 5\ ((t_a/t_c)^{.2} - t_a^{.8})]/(t_c - t_a) .$$

The additional dose after fallout cessation is given by

$$D_2 = FII(I)\ 2.71 t_c^{-0.382} .$$

The total biological dose is then the sum D_1+D_2.

Use of the model disclosed that even in low shear conditions an appreciable fallout could be deposited considerable

distances upwind or crosswind at a downwind distance of 0. In order to eliminate these physically unacceptable possibilities, the following scheme was added to the model to limit values of k_3 and k_{RL} in low shear conditions.

The total angle, θ_T, through which the wind varies during fall of each subcloud from its initial altitude to the ground, is computed in step 12. A shear correction factor, SHRFAC(I), is then computed by

$$SHRFAC(I) = 1 - \sin \theta_T.$$

In step 21 a cloud radius and cloud bottom altitude are estimated based on fits to ENW data by

$$CLDRAD = 0.2023 \sqrt{W} \quad \text{(miles)}$$

$$CLDBOT = 5.26\ W^{.27} \quad \text{(kft)}.$$

A distance to use upwind is estimated by

$$CLDBOT = CLDRAD\ (1/6 + 5/6\ (\frac{h_{xi}}{CLDBOT})^2)$$

where h_{xi} is the altitude of the ith subcloud. A k_3 min is calculated by

$$k_3 = 3.SHRFAC(I)/(\sqrt{X_{c0}{}^2(I)\ t\ Y_{c0}{}^2(I)} + 0.5CLDUSE).$$

If the selected value of k_3 is less than k_3 min, it is set equal to k_3 min.

In step 23 a crosswind diffusion is estimated based on [Ref. 14]. The diffusion standard deviation is estimated by

$$\sigma_d = 1.28 t_f \quad \text{(miles)}$$

where t_f is the fall time for the subcloud. A minimum value of k_{RL} is estimated by

$$k_{RL\ min} = 3./(CLDUSE(I) + 3.\sigma_d).$$

If the selected value of k_{RL} is less than k_{RL} min, it is set equal to k_{RL} min.

Chapter VII

PROGRAM AREA P11., DETERMINISTIC FALLOUT CALCULATIONS

A. INTRODUCTION

1. General Area Covered

Program area P11. consists of the program GRDFAL, which performs deterministic fallout calculations using either the WSEG-10 fallout model for single weapons, a simplification of this model [Ref. 7] using clusters of weapons, or appropriate combinations of the two. It is similar in general structure to the program RUBATO which was developed originally to do probabilistic fallout calculations but was later used as an expedient for deterministic fallout calculations with a single given input wind. All the probabilistic calculations were stripped from the RUBATO program, the coding mostly rewritten, and some additional capabilities added to produce the present program.

The program considers a sequence of monitor points; for each monitor point it goes through an input list of weapons (or weapon clusters) adding doses for each to the monitor point. The program is currently configured to calculate fallout on a ten minute grid covering the United States. However, the monitor points are selected through a single short subroutine so that rewriting this subroutine would allow inputting any set of monitor points desired.

The wind data input are fallout wind speed, wind direction and wind shear at each point of a wind grid; this wind grid has 2° spacing and covers the United States. A supplementary

program is available to convert daily winds to fallout winds on the required grid.

2. Summary of Major Program Areas

Only a single main program has been developed. A set of input variables control various program operating options. A supplementary program called RAWGRD is available to convert input wind data at various levels on a global polyconic grid to fallout winds on a 2° grid suitable for use in the WSEG-10 model.

B. PROGRAM DESCRIPTIONS

1. Program GRDFAL

a. Program Elements

The program consists of a main program to control the flow of subroutine calls plus the following subroutines:

- INVAL - input control variables, weapon characteristics, wind data and grid data
- INIT - initialization of fallout calculations
- CLSIN - input weapon and cluster locations and properties and associated wind data
- TGTIN - calculate locations of grid monitor points (input target locations) and associated wind data
- SQRSCN - perform fallout screening operations for weapon clusters by 1 degree grid square
- FALDOS - control fallout dose calculations
- CURVW - compute downwind and crosswind distance along curved streamlines
- DOSWRT - output calculated doses
- SPHDST - compute distances along a sphere
- PROJCT - calculate rectangular coordinate projection
- UNJCT - calculate inverse of rectangular coordinate projection
- FALLYB - do yield-dependent WSEG-10 calculations

FALLWB - do wind speed-dependent WSEG-10 calculations

FALLDB - do downwind distance-dependent WSEG-10 calculations

FALLCB - do crosswind distance-dependent WSEG-10 calculations

QFALLY - approximate WSEG-10 yield-dependent calculations

QFALFW - approximate WSEG-10 wind-dependent calculations

WFALDW - approximate WSEG-10 downwind distance-dependent calculations

QFALCW - approximate WSEG-10 crosswind distance-dependent calculations

CFALLY - cluster yield-dependent calculations

CFALWD - cluster wind, downwind distance and crosswind distance-dependent calculations

CUMMOR - calculate cumulative normal function.

The program communication is by block common. The common blocks are:

/RUNSW/ Control parameters defined by input data

/RUNPR/ Parameters varying during run

/WPNPR/ Weapon parameters

/WNDPR/ Wind values

/FLWSEG/ Fallout model inputs

/IOPR/ Input/output control.

The definitions of each of the variables in these block commons follow. Those variables which are input variables are marked by an I. For control variables, the options selected by various values are shown. Maximum dimensions of arrays are marked by an M.

/RUNSW/ = Control parameters defined by input data:

I IWPWND - Method of fallout wind calculation

1. Wind at center of cluster
   (or at weapon if no clusters)
2. Wind at target

3. Wind average of cluster and target

4. Curved wind for each cluster

I IWPUSE - Method of calculating weapon grouping

1. Cluster model only

2. Cluster for distant weapons - individual weapons nearby

3. Individual weapons only

I IMAPT - Method of distance calculation

1. Use national rectangular projection

2. Use local rectangular projection

3. Use spherical earth

I ISINGW - Exercise single weapon input and weapon class input from input data file

(Must be 1 if IWPUSE = 2 or 3)

0 = Don't exercise

1 = Exercise

I ICLUST - Exercise cluster input

(Must be 1 if IWPUSE = 1 or 2)

0 = Don't exercise

1 = Exercise

I IDCAL - Select type of dose calculation

1. Calculate standard WSEG-10 maximum equivalent residual dose

2. Calculate H+1 dose rate

3. Calculate total dose accumulated in one week

4. Calculate total dose accumulated in infinite time

M NGROD = Maximum number of grid rows

I IGRSI (NGROD) = Number of westernmost grid in its ith row

[(grid number = (50-LAT)60+(125-Long))]

I IGRS2 (NGROD) = Number of easternmost grid in the ith row

I NGRSPT = Number of grid row definitions input

I IGPTSW = Output doses on standard output medium if 1

I IGSVSW = Output doses on File NE if 1

BIASE = Constant added to easting to make all values positive

BIASN = Constant added to northing to make all values positive

I IPTDEG = print control frequency

0 = Print from grid

1 = Print only on degree intervals

2 = Print only for every other degree interval

I ICHKPT 0 - Checkpoint control, don't use checkpoint option

1 = Do use checkpoint option. Checkpoint file on mass storage

2 = Do use checkpoint option. Checkpoint file on tape

/RUNPR/ = Parameters varying during run:

IGRD - Index to grid row

JGRD - Current grid number

IGRDF - Index to fine longitude in grids

JGRDF - Index to fine latitude in a grid

YTL - Current target northing

XTL - Current target easting

WINDT - Current target wind speed

ALT - Current target wind direction, radians counter-clockwise from east

SALT - Sin of target wind direction

CALT - Cosine of target wind direction

SHRT - Wind shear at target

DOSE - Current calculated dose from a single weapon

DTOT - Current accumulated dose for a monitor point

JSCRN (NCLSD) - If Ø current large grid does not pass screening; if 1 does pass screening, do fallout calculations

ILAST - Flag, of one last grid point is calculated

SINTL - Sin of target latitude, used if IMAPT = 3

COSTL - Cosine of target latitude, used if IMAPT = 3

/WPNPR/ = Parameters defining weapons:

M NCLSD - Number of clusters dimensioned

M NWPND - Number of individual weapons

M NWPNCD-Number of weapon classes

M NCLSA=1, unless IMAPT = 3, then = NCLSD if ICLUST ≠ 0 or NWPN if ICLUST = 0

M NCLSB=1, if 1 WPWND = 2, otherwise NCLSD if ICLUST≠ 0 or NWPN if ICLUST = 0

I YLDC (NCLSD) -Effective cluster yield (log average of individual yields weighted by fission fraction)

I FISSC (NCLSD) -Cluster fission fraction (determined so YLDC (.) FISSC(.) equals the sum of yields times fission fraction summed over all weapons in the cluster)

I XC(NCLSB)-Cluster easting of IMAPT = 1, longitude otherwise

Y YC(NCLSB)-Cluster northing if IMAPT = 1, latitude otherwise

COSCLL (NCLSB) -Cosine of cluster latitude if IMAPT = 1

I SIGXC (NCLSB) -Cluster East-West standard deviation fission yield weighted (input as degrees, then converted to statute miles)

I SIGYC (NCLSB) -Cluster North-South standard deviation fission yield weighted (input as degrees, then converted to statute miles)

SARY (NCLSD,5)-Yield-dependent parameters for use in cluster model

WINDC (NCLSB) -Wind speed at cluster center (miles/hr)

ALC (NCLSB) -Wind direction at cluster center (radian counter-clockwise from east)

SHRC (NCLSB) -Wind shear at cluster center (mph/kft)

SINC (NCLSA) -Sine of wind direction

COSC (NCLSB) -Cosine of wind direction

LSTWPC (NCLSA) -Number of last weapon in cluster

NCLS -Number of clusters

I	XWPN (NWPND)	- Weapon easting if IMAPT = 1, longitude otherwise
I	YWPN (NWPND)	- Weapon northing if IMAPT = 1, longitude otherwise
I	IWPNC (NWPND)	- Weapon class
I	NWPN	- Number of weapons
I	YLDWC (NWPNCD)	- Weapon class yield (MT)
I	FISSWC (NWPNCD)	- Weapon class fission fraction
I	CEPWC (NWPNCD)	- Weapon class delivery error, CEP (miles)
I	HOBWC (NWPNCD)	- Weapon class height of burst (feet)
I	DELWC (NWPNCD)	- Weapon class reliability
I	NAMEWC (NWPNCD,4)	- Weapon class description, up to 16 characters
	ARRYWC (NWPNCD,6)	- Yield-dependent weapon class values for use in WSEG-10 calculations
	NWPC	- Number of weapon classes
	YLDI(9)	- Mean value of yield for grouped yield intervals used in WSEG-10 calculations
	YLDM(8)	- Separating values for grouped yield intervals used in WSEG-10 calculations
	QARYL(7, 19)	-Yield-dependent values used in WSEG-10 calculations for grouped yield intervals
	SINCLL (NCLSA)	- Sin of cluster latitude, used if IMAPT = 3

/WNDPR/ = Wind values:

M	NIWGRD	- Number of dimension and wind points east-west
M	NJWGRD	- Number of dimension and wind points north-south
I	SPDMO (NIWGRD, NJWGRD)	- Wind speed at grid point input in knots used, (e.g., a west to east wind is 270 deg.)
I	SHRMO (NIWGRD, NJWGRD)	-Wind shear input as knots/kft, used as miles/hr

/FLWSEG/ = Fallout model inputs:

YIELD = Weapon yield (MT)

FISS = Weapon fission fraction

HOB = Height of burst (ft.)

EFW = Effective fallout wind (mph.)

SC = Wind shear (mph/kft.)

DWD = Downwind distance (miles)

CWD = Crosswind distance (miles)

MDCAL = Type of dose to calculate, see IDCAL

TWPN = Time of weapon detonation

ARRY(40) = Storate array for temporary values

XL = For cluster model, cluster length

SIGW = For cluster model, crosswind standard deviation of weapon fission yield weighted distances

DOSEM = For cluster model, output dose

XTRA = Product of cluster sigmas for use in WSEG-10 routines

/IOPR/ = Input/Output control:

MP = Standard input (unit 5 in Univac system)

MQ = Standard output (unit 6 in Univac system)

NC = Weapon input

ND = Parameter and wind input

NE = Save file output.

b. Operating Procedures

(1) General

The program requires two input files be made available. One file contains input parameters and is currently named P11.INPPAR. Another file inputs weapon data and is currently called P11.WPNS. The user may modify these file names by changing lines 8, 2 and 5 in element P11.QGRDFAL. Output from

the program is written either on the standard output file or file P11.DOSSAV. To initiate program execution once the input files are defined, type: @ADD P11.QGRDFAL.

(2) Input Elements

The input elements in the file INPPAR are described below. The lines labeled Blank may contain any set of 80 characters. For ease in preparing input data, the names of the variable on the succeeding line of input may appear in the blank lines:

Line 1 Blank

Line 2 Calculation control

Variables IWPWND, IWPOSE, IMAPT, ISINGW, ICLUST, IDCAL,

Format (6I10)

The variable meanings are given in the previous section. The variables ISINGW and ICLUST are included to ensure that the weapon data read consistent with the actual content of the input file WPNS. This allows changing calculation types without having to change the input weapon files. Thus, for example, if the weapon file has both single weapons and clusters, but only clusters are to be used in the calculation, then one must have IWPUSE=3, ISINGW=1 and ICLUST=1.

Line 3 Blank

Line 4 Output control

Variables IGPTSW, IGSVSW, IPTDEG, ICHRPT

Format (4I10)

If ISVNGW = 0, skip line 5

Line 5 Weapon class characteristics for ith weapon

Variables: YLDWC(I), FISSWC(I), CEPWC(I) HOBWC(I), DELWC(I), (NAMEWC(I), I=1,4)

Format (5F10.0,4A4)

One entry is made for each weapon class. The end of this input string is flagged by adding a line where the value of YLDWC(I) is -1.0.

Line 6 Wind data

Variables FLAT, FLON, ((SPDMD(I,J), DLGMD(I,J), SHRMD(I,J))

Format (5 F10.4)

One entry is made for each grid point. The grid increases in latitude from 24 to 50 degrees by 2° increments and in longitude from 65 to 125 degrees by 2° increments. The variables FLAT and FLON may be 0 if desired. They are written on the wind input data only for convenience in manually using the file. The velocities are input in knots and immediately converted to miles/hr. The wind grid data may be directly obtained as output from the program LEVGRD.

Line 7 - Number of grid control inputs
Variable NGRSPT
Format (I5)

Line 8 - Grid control variables
Variables IGR5I(I), IGR52(I)
Format (2I5)

These variables control the definition of the grid covering the United States from which monitor points are obtained. See the discussion on algorithms implemented in subroutine TGTIN for a more complete definition of these variables.

The weapon input is in the file WPNS and is read by the subroutine cluster. The first section of the file defines the weapon cluster which is read if ICLUST=1. The ith cluster has the following input:

Variables: YLDC(I), XWLON, YWLAT, SIGXS, SIGYS, XMNLN, XMXLN, XMNLT, XMXLT, FISSC(I), NWPNN, NUMC, LSTWPC(I)

Format (F6.3, 2F7.3, 2F6.3, 2F7.3, 2F6.3, F7.3, 2I4,I5)

XWLON and YWLAT are the weapon longitude and latitude in degrees. If IMAPT ≠ 1, they are directly placed in XC(I) and YC(I), otherwise they are converted to an easting and northing and then placed in XC(I) and YC(I). SIGXS and SIGYS are yield-weighted standard deviations of the cluster in degrees. After conversion to statute miles, they are placed in SIGXC(I) and SIGYC(I). The variable NWPNN is the number of weapons in the cluster. The variables XMNLN, XMXLN, XMNLT, and XMXLT are the minimum and maximum longitudes and latitudes of any weapons in the cluster. These variables and the variable NVMC are not used in this program. The other variables are as defined for common block /WPNPR/. The end of the input is flagged by an additional line of input with the value of YLDC(I)=-1.

The next section of input is the list of individual weapons, which is read if ISINGW=1. For the ith weapon the following line is read:

Variables FLAT, FLON, IWPNC(I)

Format (2F10.0, I4)

FLON and FLAT are weapon longitude and latitude in degrees. If IMAPT≠1, they are directly placed in XWPN(I) and YWPN(I), otherwise they are converted to eastings and northings and they are placed in XWPN(I) and YWPN(I). IWPNC(I) is the weapon class which is used to define weapon yield, etc. through the variables YLDWC(IWPNC(I)), etc.

C. Algorithms Implemented

The algorithms implemented will be described by subprogram except for the fallout models and coordinate projection which have already been described in [Ref. 4].

Program GRDFAL

The program flow is straightforward. At the start the subprograms INVAL, CLSIN and INIT are called. Then a loop is entered where the subprogram TGTIN is called to produce a new monitor point, SQRSCN is called only as each new one degree square is entered for fallout screening calculations, FALDOS is called to monitor the fallout calculations, and finally DOSWRT is called to write results. When the last monitor point has been used, the subroutine TGTIN sets the flat ILAST, which is used by the main program to end the calculations.

Subroutine INVAL

This subroutine directly reads input data from the input file INPPAR, as described in the input section.

Subroutine INIT

This subroutine calculates the yield-dependent parameters for the WSEG-10, approximate WSEG-10, and cluster model by calls to the subroutines FALEYB, QFALLY, and CFALLY.

Subroutine CLSIN

This subroutine inputs weapon and weapon cluster data. If IMAPT=1, subroutine PROJCT is called with projection option 3 to obtain eastings and northings. If required by the parameter IWPWND, wind properties are computed at the weapon points. To do this the indices I,J of the southeast corner of the grid square are found by:

$$I = (LATW-24)/2$$
$$J = (LONGW-65.)/2$$

where: LATW, LONGW are weapon latitude and longitude.

I and J are truncated to the next lowest integer. x and y are the fraction of the distance in the wind square to the east and to the north from the weapon location. The value of wind speed, wind direction and wind shear are then obtained by linear interpolation from the four surrounding corners. If V_{ij} is the value of one of these variables at the i, j grid point and V is the value at the desired location, then:

$$V = V_{ij}(1-x)(1-y) + V_{i+1,J}(x)(1-y) + V_{i,j+1} \cdot (1-x)(y) + V_{i+1}(x)(y) \quad .$$

Subroutine TGTIN

This subroutine finds the latitude and longitude over a ten minute grid covering the United States. The grid was developed by J. Jacobs and J. Backman of FEMA. The latitude and longitude of the southwest corner of one degree by one degree grid squares are defined by a grid index through the following relation:

$$JGRD=(49-LATD)\ 60+(125-LOND)+1$$

where LATD and LOND only assume integer values. Increasing JGRD will sweep a swath of one degree grid points decreasing in longitude across the county at constant latitude. For each of these rows, the input values IGRS1(JGRD) and IGRS2(JGRD) define the westmost and eastmost longitude covered, where JGRD is an index to horizontal rows at constant latitude. The algorithm sweeps across rows from west to east using an index IGRD. After a row is completed, JGRD is increased by one to sweep the next most northern row. For each one degree figure, a series of ten minute grid points are then generated first increasing latitude from south to north using the index JGRDF, and, when a vertical column of six points is completed, new

columns are generated by increasing the index IGRDF, decreasing longitude from west to east. Each call to the subroutine TGTIN produces a new grid point. If needed the target coordinates as computed in x,y coordinates and wind values at the target point are computed. Changing the values of the input arrays IGRS1 and IGRS2 would allow scanning only selected areas of the county.

Subroutine SQRSCN

This subroutine is called whenever a new one degree square is entered. It determines if a cluster (or weapon) could produce significant fallout doses on the center of the one degree squares. The screening distances are increased slightly to allow for the finite square rise. If the screening test is passed for the ith cluster, a value of 1 is returned for JSCRN (i), if it is not passed and no significant doses are possible, a value of 0 is returned. For the ith cluster a value CMAX is computed by:

$$CMAX=1200 \cdot SIGXC(I)+SIGYC(I)+40$$

where SC is the appropriate shear value

SIGXC(I) is east west cluster standard deviation
SIGYC(I) is north south cluster standard deviation.

If individual weapons are considered, ICLUST=0, SIGXC and SIGYC are taken as zero. If CMAX is less than 140 or greater than 340 it is limited to these values. The downwind distance DWD and the crosswind distance CWD are computed using appropriate coordinates and wind transformation. If the crosswind distance is greater than CMAX the screening test is not passed. If the downwind distance satisfies the following relation

$$DWD< - \left\{140 + 2(SIGXC(I)+SIGYC(I))\right\}$$

the screening test is not passed.

Subroutine FALDOS

This subroutine controls the calling of the appropriate fallout models and accumulated dose on a monitor point. It is primarily a bookkeeping routine with the emphasis on obtaining the proper values of fallout winds and downwind and crosswind distances under the various input options. The specific assumptions made (outside of bookkeeping) are: If IWPUSE=2 the cluster model is used if downwind distance is greater than 100 miles, and the individual weapons are used otherwise. For the cluster calculation the cluster model is used directly if wind speed is greater than 5 mph. Subroutines CFALLY and CFALWD and the appropriate WSEG-10 model (subroutines QFALLY, QFALFW, QFALDW, QFALCW) are used for lower wind speeds.

Subroutine CURVW

This subroutine performs integration along a wind streamline to compute downwind and crosswind distances. Rather large integration distances of 150 miles are chosen to provide a resolution in the integration compatible with the resolution of the input wind grid.

If the weapon to target distance is less than 150 miles then the average wind direction at target and weapon locations is used to compute downwind and crosswind distances. Otherwise the integration uses wind direction at the beginning of a 150 mile step to get increments in distance along the wind streamline. Near the target the wind at the target is used for the final wind streamline direction. A perpendicular from this final segment of the wind streamline to the target is used for the final calculation of downwind and crosswind distances. The effective fallout wind velocity is obtained by computing the distances a particle would be carried along the wind streamline until the time of fallout deposition defined in the WSEG-10 model. This distance, divided by the fallout deposition

time, is used as the effective wind velocity returned as an output of the subroutine.

Subroutine SPHDST

This subroutine computes distances on a spherical earth using standard spherical geometry formulas and an earth radius of 3962.2258 miles. If the difference in latitude is less than four degrees and the difference in longitude is less than five degrees, then the distance is computed assuming a flat earth using a latitude which is the average of the latitude of the two end points.

Fallout and Distance Projection Subroutines

These subroutines are the same as described in [Ref. 4] and will not be repeated here. The one exception is to allow the WSEG-10 model to return either one week or infinite time doses. These doses are readily obtained by analytic integration of the dose rate assuming a $t^{-1.2}$ decay rate.

2. Program LEVGRD

This program is identical to that described in program area P12. and will not be described here.

Chapter VIII

PROGRAM AREA P12., WEAPON ORIENTED FALLOUT CALCULATIONS--PROGRAM GUISTO

A. INTRODUCTION

This program computes fallout desposition using the WSEG-10 fallout model. It differs from most fallout desposition models in that for a particular weapon the desposition at all monitor points of interest is computed, and then weapons are considered in succession; rather than the usual procedure of adding the dose for all weapons affecting a single monitor point, and then considering all monitor points in succession. In this approach the parameters for only one weapon at a time need be considered, thus effecting a considerable savings in time, but it does require the simultaneous availability of all monitor points to store fallout doses, which gives rise to rather large computer core storage requirements.

The monitor points are chosen to form a square grid in a plane which is an Albers Equal Area Projection of the United States; i.e., a square grid drawn on an Albers Equal Area map of the United States. For most applications, a grid ten miles on a side appears appropriate, so each grid square covers an area of 100 miles on the map (divided of course by the square of the map scale factor). Since this is an equal area projection, by definition each square on the map also covers exactly 100 square miles on the surface of the earth, although due to the map transformation the shape of the earth is distorted somewhat from a square.

The fallout doses are computed on a square grid with the same spacing as for the monitor grid points. This grid is oriented with one axis downwind and the other axis crosswind. The fallout dose computed is then allocated to the nearest monitor points. The same grid spacing is required so that no bias is obtained in the fallout doses deposited. If, for example, the fallout calculations were done for grid points with one half the spacing of the monitor grid, then, on average, each monitor point would receive doses from four fallout points and the dose would be overestimated by a factor of four. Of course, this could be compensated for by multiplying the fallout dose by 1/4, however, for computational efficiency the two grids should probably be about the same size.

This method of procedure leads to two computational efficiencies. The first is that fewer calls need be made to the wind speed and downwind distance portions of the WSEG-10 model; the second is that screening calculations do not have to be made for each combination of monitor point and weapon. This results in a decrease in computer running time for a nationwide attack by about a factor of 10 compared to the program GRDFAL. Furthermore, since one weapon at a time is considered, weapons can be added or deleted from an attack by simply adding or subtracting the doses from these weapons. This feature makes this program potentially useful for calculations in real time use where weapon reports do not come in all at once, but where estimates are desired based on those weapons reported to date.

The direct outputs of this program are doses on an Albers Equal Area grid. Such a grid, superimposed on an Albers Equal Area map of the United States, would give directly a pictorial representation of the fallout deposited. If a different set of monitor points is desired, then a supplementary calculation must be performed to interpolate from the Albers grid. The program MINGRD performs this interpolation to give doses on the

same ten minute grid covering the United States as is in the program GRDFAL.

A program RAWGRD has been developed to convert winds from winds a five levels for a particular day to fallout winds on a two degree grid for use in the program GUISTO. (This program is also used to produce winds for the program GRDFAL.) This program as currently configured takes winds from one month of the twelve "most probable" winds [Ref. R. Mason of CCTC].

B. PROGRAM DESCRIPTIONS

1. Program GUISTO

a. Elements in Program

The program consists of the following program elements:

GUISTO - manages subroutine calling sequences

INVAL - reads control parameters, reads wind data, and converts wind data to an Albers grid

CLSIN - reads weapon data and calculates winds at weapon

INIT - initialization of WSEG-10 yield-sensitive calculations

CALDOS - manages fallout model calls for downwind and crosswind variations and stores values in Albers grid

DOSWRT - outputs grid doses to standard output medium or to permanent storage

TRMPNT - outputs doses on a standard terminal printer in form of a dose map

PLTDIR - outputs doses on a special plotting terminal in the form of a dose map

ALBERS - performs transformation from latitude, longitude to Albers Equal Area map coordinates, and also the inverse transformation

FALLYB, FALLWB, FALLDB, FALLCB - performs yield-dependent, wind speed-dependent, downwind distance-dependent, and crosswind distance-dependent WSEG-10 fallout model calculations

Communication between subprograms is through block common. These common blocks are:

/RUNSW/	Control parameters defined by input data
/RUNPR/	Parameters varying during run or controlling grid storage
/WPNPR/	Parameters defining weapons
/WNDPR/	Parameters defining wind
/FLWSEG/	Parameters used by WSEG-10 model.

The following list presents definitions of these block common variables.
(I denotes an input variable)

/RUNSW/ = Control parameters defined by input data:

I IWPWND - Method of allocating fallout winds

1. Use wind at weapon for entire calculation for that weapon
2. Use wind speed at weapon and wind direction along streamline
3. Use wind direction along streamline, modify downwind distance increment by ratio of weapon wind speed to local wind speed

I INTERP - Method of distributing fallout dose over Albers grid

0 = Allocate all of the dose to the nearest corner

1 = Allocate dose proportionately to the four corners of the square containing the grid point

I ICHKPT - Control of checkpointing

0 = Don't do checkpoint

1 = Do checkpoint dumps with output file on mass storage

2 = Do checkpoint dumps with output file on magnetic tape

I IGPTSW - If 1, output grid doses on standard putput medium

I IGSVSW - If 1, output grid doses to file NE

I IGPTSW - If 1, only output doses to standard output medium every 10 grid points; if 2, every 100 grid points

BIASE - Distance of 1432.672 miles added to eastings to keep all distances positive

BIASN - Distance of 977.414 miles added to northings to keep all distances positive

I ITRPSW - If 1, plot map using a normal terminal as a plotting device

/RUNPR/ = Parameters varying during run or related to grid control:

DSEARY(KIDSA, KJDSA) - Array for storing doses on square grid in Albers Equal Area projection plane

I IMMIN - Minimum i (west) coordinate on grid for this run (minimum usable value is 1)

I IMMAX - Maximum i (east) coordinate on grid for this run (maximum value is IMMIN + KIDSA - 1)

I JMMIN - Minimum j (south) coordinate on grid for this run (minimum usable value = 1)

I JMMAX - Maximum j (north) coordinate on grid for this run (maximum value is JMMIN + KJDSA - 1)

ILAST - Flag to indicate last weapon has been input if 1, otherwise 0

IMMAXP = IMMAX+1

JMMAXP = JMMAX+1

IMMINM = IMMIN-1

JMMINM = JMMIN-1

KIDSA - Dimension of dose storage array DOSARY in the i (east-west) direction. The variable value must be set equal to that in the dimension statement for DSEARY.

KJDSA - Dimension of dose storage array DSEARY in the j (north-south) direction. The variable value must be set equal to that in the dimension statement for DSEARY.

DELGRD - Grid spacing in miles

DSEMIN - Cutoff dose level in controlling limits of dose calculations

/WPNPR/ = Parameters defining weapons:

XC = Weapon easting on Albers grid

YC = Weapon northing on Albers grid

WINDC = Wind speed at weapon (miles/hour)

ALC = Wind direction at weapon (radians counterclockwise from the east)

SHRC = Wind shear at weapon (mph/kft)

SINC = Sine of weapon wind direction

COSC = Cosine of weapon wind direction

NWPN = Number of weapons input

IWPNC = Index to weapon class

I YLDWC(IWPNC) = Weapon class yield (MT) for Ith weapon

I FISSWC(IWPNC) = Weapon class fission fraction

I CEPWC(IWPNC) = Weapon class delivery error (miles)

I HDBWC(IWPNC) = Weapon class burst height (feet)

I DDLWC(IWPNC) = Weapon class reliability

I NAMDWC(IWPNC,4) = Weapon class name

I ARRYWC(IWPNC,6) = Weapon class yield-dependent calculation results for use in WSEG-10 model

/WNDPR/ = Wind-dependent parameters:

I SPDMO(I,J) = Wind speed at node of 2 degree grid (mph)

I DEGMO(I,J) = Wind direction at node of 2 degree grid (degrees counterclockwise from north)

I SHRMD(I,J) = Wind shear at node of 2 degree grid (mph/kft)

SPDGD(IG,JG) = Wind speed at node of 100 mile grid in Albers plane (mph)

DEGGD(IG,JG) = Wind direction at node of 100 mile grid in Albers plane (degrees counterclockwise from north)

SHRGD(IG,JG) = Wind shear at node of 100 mile grid in Albers plane (mpg/kft)

DELWND = Wind grid spacing in Albers plane (miles)

IWGMAX = East West number of wind grid points in Albers plane (currently equal 31)

JWGMAX = North South number of wind grid points in Albers plane (currently equal 14)

/FLWSEG/ = Fallout model inputs:

YIELD = Weapon yield (MT)

FISS = Weapon fission fraction
HOB = Height of burst (ft)
EFW = Effective fallout wind (mph)
SC = Wind shear (mph/kft)
DWD = Downwind distance (miles)
CWD = Crosswind distance (miles)
IDCAL = Type of dose to calculate
1 = WSEG biological dose
2 = H+1 hour dose rate
3 = One week dose
4 = Infinite time dose
TWPN = Time of weapon detonation
ARRAY(40) = Storage array for temporary values
XL = Cluster model variable, not used in this program
SIGW = Cluster model variable, not used in this program
DOSEM = Output dose
XTRA = Cluster model variable, not used in this program

/IOPR/ = Input/Output Control:
MP = Standard input (unit 5 in Univac system)
MQ = Standard output (unit 6 in Univac system)
NC = Weapon input
ND = Parameter and wind input
NE = Save dose output
NF = Terminal print output.

b. Operating Procedures

(1) General

The program is run by adding the appropriate program elements to the run stream. For running with a grid covering the entire United States, a means of running both in the demand mode and in the batch mode are available. Since using this size grid requires about 64,000 words of computer memory, another set of program elements is available using a smaller grid. Using this size grid of 50 x 150 squares (covering 500 x 1500 miles)

requires only a total of 20,000 words of computer memory. The types of run elements used in these three cases are identified by a prefix before the program (GUISTO) name. For subprograms, the prefix preceeds the subprogram name. These prefixes are given in the following table. The prefixes for the small grid demand run are the standard set defined earlier. The prefixes for the other types deviate from the standard set.

TYPES OF ELEMENTS	PREFIX		
	Small Grid Demand Run	Large Grid Demand Run	Large Grid Batch Run
Main Program Source Element	N	I	D
Subprogram Source Element	N	T	T
Main Program Relocatable Element	R	F	E
Subprogram Relocatable Element	R	F	F
Absolute Element	S	H	L
Map Procedure to Create Alsolute Element	V	G	K
Procedure to Initiate Run	Q	J	B
Prodedure to Terminate Run	P	P	C

Thus, for example, to initiate a demand run with a small grid, the element P12.QGUISTO should be added to the run stream. To initiate a demand run with a large grid, the element P12.JGUISTO should be added to the run stream.

(2) Input Elements

Two input files must be available, a set of control wind parameters and a list of weapon locations. The definitions of the input parameters are given in the block common definitions. The input has a number of skipped records which may be used to give the names of the variables to be defined on the next record. They are indicated by the word Blank.

Record 1 Blank
Record 2 Run Control Parameters
Variables: IWPWND, INTERP, IDCAL
Format (3I10)

These parameters control the type of calculation. Setting IWPWND=1 and INTERP=0 will make the calculation somewhat more rapid. However, the time saving is probably not worth the loss in accuracy, so recommended values are IWPWND=3, INTERP=1, and (if WSEG biological dose is desired) IDOAL=1.

Record 3 Blank

Record 4 Grid Size Parameters

Variables: IMMIN, IMMAX, JMMIN, JMMAX

Format (4I10)

These parameters contain the size and location of the Albers grid, with IMMIN and IMMAX controlling the east-west location and JMMIN and JMMAX controlling the north-south location. Figure 40 shows this grid on a United States map. To cover the entire United States the following values are required: IMMIN=1, IMMAX=289, JMMIN=1, JMMAX=178. The dimensions of the array DSEARY, given to the variables KIDSA and KJDSA, must be set large enough to contain these points. The minimum values of variables KIDSA and KJDSA are given by KIDSA=IMMAX-IMMIN+1 and KJDSA= JMMAX-JMMIN+1. A check is made when reading input to ensure this condition holds. An error stop is made if this condition is violated. Since the array dimension can only be changed by recompilation of the program, the variables KIDJA and KJDSA are defined by data statements in program GUISTO and can only be changed by recompilation.

Record 5 Blank

Record 6 Output Control Parameters

Variables: IOPTSW, IGSVSW, IPTDEG, ITRPSW, ICHKPT

Format (5I10)

Records 7 to 7+NWPC Weapon Class Parameters

Variables: YLDWC(I), FISSWC(I), CEPWC(I), HOBWC(I), DELWC(I), (NAMEWC(I,J),J+1,3)

Format (5F10.0,4A4)

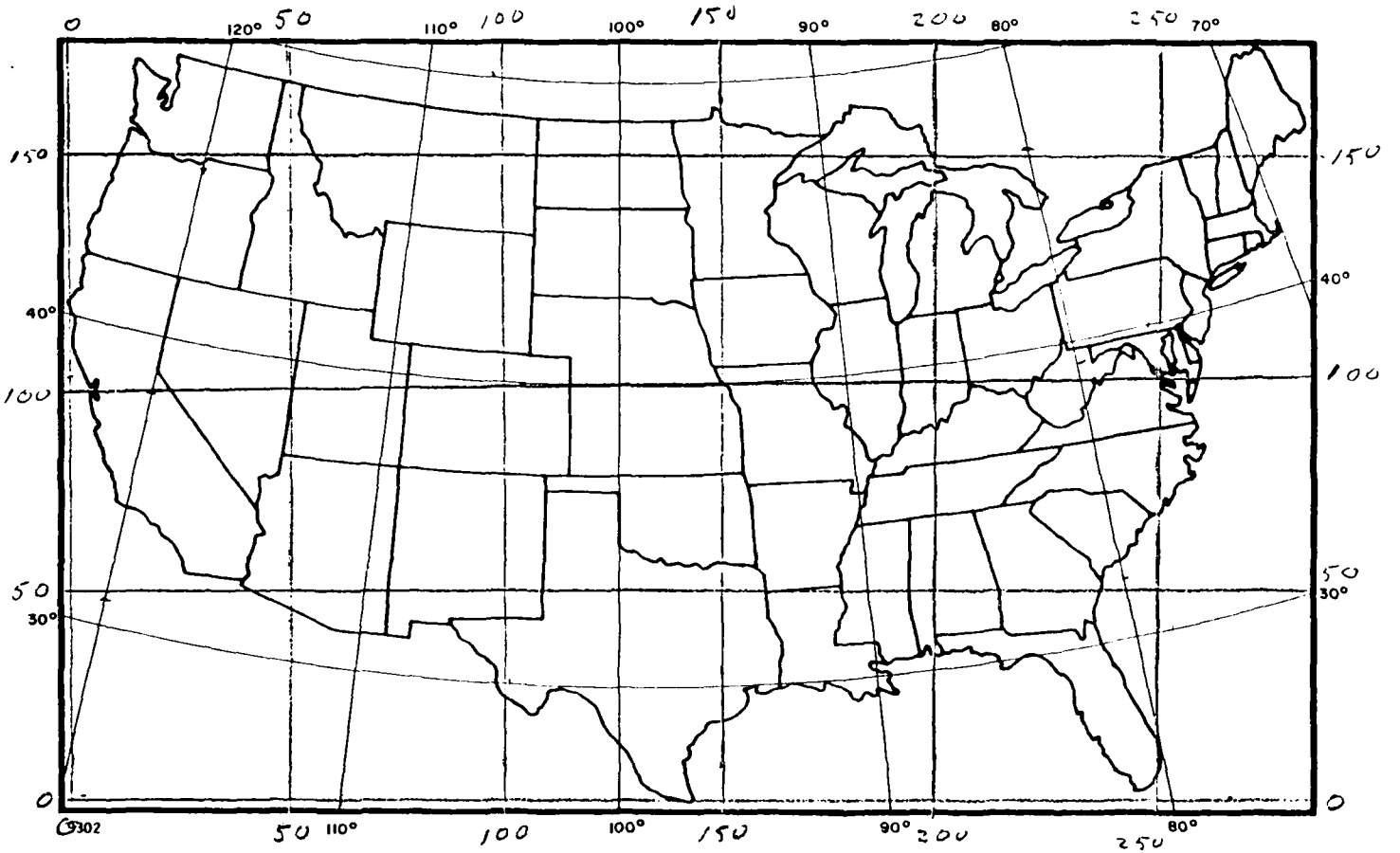


Figure 40. ALBERS GRID ON A UNITED STATES MAP

In this program only YLDWC, FISSWC, and HOBWC are used. Any values may be used for the other variables. Any change in any values of the variables YLDWC, FISSWC or HOBWC requires a new weapon class. Each separate weapon class requires an individual record.

Records 7+NWPC to 7+NWPC+434

Variables: (SPDMO(I,J), DEFMO(I,J), SHRMO(I,J), I=1,14) J=1,31

Format (20X, 3F10.4)

These records are fallout wind speed, direction and shear on a two degree grid using from 25 to 50 degrees latitude and from 65 to 125 degrees longitude. The wind speed and shear are input in knots and immediately converted to miles/hour. The wind direction is input in degrees counterclockwise from the north. The wind data may be prepared in this format from a daily wind by using the program SHRGRD. The second file needed for input defines the weapons, with one record for each weapon processed. The input is

Variables: FLAT, FLON, IWPNC

Format 2F10.0,I4

Here, FLAT is the weapon latitude, FLON is weapon longitude, and IWPNC is weapon class.

c. Algorithms Implemented

The algorithms implemented will be described by subprogram. Obvious bookkeeping steps will be omitted to simplify the discussion.

Program GRDFAL

The main program guides the calls to other subprograms. To start the program, the subroutines INVAL and INIT are called; for each weapon, subroutine CLSIN is then called to read data for that weapon, and CALDOS is called to process this weapon.

These pairs of subroutine calls are repeated until all weapons have been processed. Finally the subroutines which output the grid doses are called.

Subroutine INVAL

In addition to reading input data, this subroutine puts the wind data on a rectangular grid in the Albers plane with 100 miles spacing. To do this the latitude and longitude of each grid point are found by calling the subroutine ALBERS for the inverse transformation. Linear interpolation is then performed on the input wind grid, which has 2 degree spacing, to find wind values. On the Albers grid, since the conical Albers transformation performs a local rotation of the coordinate system, this rotation is added to the wind direction.

Subroutine CLSIN

This subroutine reads individual weapons and locates the weapons on the Albers grid. The grid coordinates are XC, YC. In addition, the wind at the weapon is obtained by interpolation on the Albers grid. After the last weapon has been processed, ILAST is set to 1.

Subroutine CALDOS

This subroutine calculates the fallout dose at a set of grid points related to weapon location and wind directions and distributes these doses to the storage grid DOSARY. If the parameter IWPWND is set to one, the downwind direction of the weapon grid points in the direction of the wind at the weapon, and the crosswind directions are perpendicular. The grid spacing is variable, but currently set to ten miles, the same spacing as the storage grid. If the parameter IWPWND is not one, the downwind distance is increased, in a succession of steps, by a distance of ten miles in the direction of the local wind. At each downwind distance, the crosswind distance is perpendicular to the local wind direction. Within the accuracy

of this ten mile integration, the hot line of the fallout follows the wind stream.

If the value of IWPWND is three, an attempt is made to compensate for varying wind speed by multiplying the distance increase by the ratio to wind speed at the weapon to local wind speed. To preserve normalization, the doses must also be multiplied by this ratio.

Upon entering the calculation, the wind-velocity-sensitive portions of the WSEG-10 calculations are performed. The program then steps upwind in ten mile steps until the hot line dose is less than the value of DOSMIN, currently set at 1R. The program returns to ground zero and then steps downwind until the hot line is less than DOSMIN.

At each downwind distance, the downwind-distance-sensitive portion of the WSEG-10 model is called to get the hot line dose. Distances are then stepped off by ten mile increments in the crosswind direction, and doses calculated at the grid points, until the dose is less than DOSMIN.

After proceeding for 100 miles, a check is made to see if none of the locations for a given downwind distance are within the storage grid. If this is the case, the calculation for this weapon is terminated since the pattern has been blown outside the region of interest.

If the switch INTERP is 0, at each calculated point the dose is allocated to the nearest storage grid point. If the switch INTERP is 1, the dose is allocated to the four surrounding grid points, by linear interpolation. If I,J are the coordinates of the grid point southwest of the calculation point, and f_x is the fraction of the grid spacing distance from the point I,J to the calculated point in increasing J direction (north), then the dose to be added, D_A, is added to the stored dose D_G by:

$$D_G(I,J)=D_G(I,J)+D_A(1-f_x)(1-f_y)$$
$$D_G(I+1,J)=D_G(I+1,J)+D_A f_x(1-f_y)$$
$$D_G(I,J+1)=D_G(I,J+1)+D_A(1-f_x)f_y$$
$$D_G(I+1,J+1)=D_G(I+1,J+1)+D_A f_x f_y \quad .$$

Subroutine ALBERS

This subroutine obtains rectangular coordinates x,y from input latitude, L, and longitude, λ, or vice versa, by an Albers Equal Area projection with standard parallels at 29.5 and 45.5 degrees latitude, centered at a longitude of 97°.

The direct transformation uses standard formulas, presented below:

call $\theta = n\ (97-\lambda)$

call $\sin\beta = \dfrac{\sin L(1+2/3\ e^2\ \sin^2 L+3/5\ e^4\ \sin^4 L+4/7\ e^6\ \sin^6 L)}{1+2/3\ e^2+3/5\ e^2+4/7\ e^6}$

where e is the earths eccentricity.

Then $\rho = (\rho_2/2 + K(\sin\beta_2-\sin\beta))^{1/2}$

where m, ρ_2, K and $\sin\beta_2$ are constraints for this choice of standard parallels and are equal to:

$$n = 0.6029$$
$$\rho_2 = 5726.0409$$
$$K = 5.1987 \times 10^7$$
$$\beta_2 = 29.5^{\circ} \ .$$

Then

$$x = \rho \sin\theta$$
$$y = \rho_0 - \rho\cos\theta$$

where $\rho = 5005.9339$.

The inverse transformation is obtained iteratively. Given x,y, compute

$$\rho = (x^2+(\rho_o-y)^2)^{1/2}$$

$$\theta = \tan^{-1}(x/(\rho_o-y)$$

$$\lambda = 97 - \theta/n$$

$$\sin \beta = \sin\beta_2 - (\rho^2-\rho_2^2)/K.$$

Then compute a first approximation to the sine of the latitude by:

$$\sin L_t = \frac{\sin \beta \ (1+2/3\ e^2 + 3/5\ e^4 + 4/7\ e)^6}{1 + 2/3\ e^2 \sin^2 \beta + 3/5\ e^4 \sin^4 \beta} \quad .$$

Finally compute

$$\sin L = \frac{\sin \beta \ (1+2/3\ e^2 + 3/5\ e^4 + 4/7\ e)^6}{1 + 2/3\ e^2 \sin L_T + 3/5\ e^4 \sin^4 L_T + 4/7\ e^6 \sin^6 L_T}$$

and the latitude by

$$L = \sin^{-1}(\sin L_T) \quad .$$

For the latitudes of the continental United States, this procedure yields an error of less than 10^{-5} degrees.

2. Program MINGRD

a. Elements in Program

The program generates output dose data on a ten minute grid covering the United States from input dose data on a ten mile Albers Equal Area grid. It consists of the following elements:

MILGRD - Main calculation

TGTIN - Generates ten degree grid points. This is the same subroutine in the program GRDFAL.

ALBERS - Performs transformations from latitude and longitude of an Albers Equal Area projection. This is the same subroutine as in the program GRDFAL.

The following common blocks--RUNSW, RUNPR, GRIDPR, IOPR--are in the program. Except for the block GRIDPR these are the same as in the program GUISTO. The common block GRIDPR

contains the variables used to control the ten minute grid generation. They are IGRS1, IGRS2, IGRD, JGRD, IGRDF, JGRDF, NGRSPT, TRGGLA, TRGGLO. These parameters are defined in the documentation for the program GRDFAL.

b. Operating Procedures

The program is run by adding the element P12.QMINGRD to the run stream. Two input files must be available to the program. The first file contains the input parameters necessary to define the ten minute grid. These are the same data as are used in the grid definitions from the program GUISTO. An output file must also be available to receive the array of doses on the ten minute grid. Each output file record contains the four defining parameters--IGRD, JGRD, IGRDF, JGRDF--grid point latitude and longitude, and the dose. The output format is 4I4, 2F9.4, F10.4.

c. Algorithms Implemented

The program is primarily a bookkeeping program. The program is initiated by reading the grid definition parameters and the Albers grid doses. A check is made of the header record for the dose data to ensure the dimensions of the program array are large enough to contain input data; if not, an error stop is made.

Next a series of calls on the subroutine TGTIN are made to generate a series of ten minute grid points. For each grid point, a call to the subroutine ALBERS is made to generate a location on the Albers grid. A check is made to ensure the point is on the Albers grid; if not, an error stop is made. If the point is inside the grid, then linear interpolation is performed on the four surrounding Albers grid points to get the dose at the target point. The dose is then written on the cutput file. The process is repeated until all ten minute grid points have been generated by the subroutine TGTIN, at which point the program is terminated.

3. Program RAWGRD

a. Elements in Program

This program converts either fallout winds or raw winds on the grid used by Global Weather Central for daily wind reporting to winds on a two degree grid covering the United States. The program consists of a single main program with no subprograms.

b. Operating Procedures

The program is initiated by adding the element P12.RAWGRD to the run stream. An input file must be available which consists of fallout winds on the GWC grid if the parameter IOCT=1, or raw winds on the GWC grid if the parameter IOCT=2. The parameter IOCT is currently set to 2 on the program. Only this option will be described since the other option is obtained by simply bypassing some calculations. An output file to receive the grid winds must also be made available to the program. When the program is initiated, tne prompt "input first three letters of month desired" will be received. The month is selected by typing the first three letters of the name and a carriage return.

c. Algorithms Implemented

The program is mostly bookkeeping. When the program is initiated, the wind data are read into storage. The wind data are at five levels: 700, 500, 300, 200 and 100 millibars, labeled A to E. Only data for wind grid coordinates II=1 to 22 and JJ=1 to 14 are saved since this is adequate to cover the continental United States.

The wind data are averaged as they are read to get fallout winds. The averaging method is the same as in the SIDAC program of the Command and Control Technical Center. Since only higher yield weapons are considered in the assessment program, only high level fallout winds are used. The effective fallout wind

at level E, W_f^E is obtained from the raw wind at other levels, W^A to W^E, by

$$W_f^E = 0.19W^E + 0.17W^D + 0.16W^C + 0.184W^B + 0.289W^A \ .$$

The averaging is actually done on the north-south and east-west components of the wind. The constants are based on the average time a particle stays at the various levels in its descent. To compute a wind shear, the fallout wind at level is also needed. This is computed by

$$W_f^D = 0.117W^D + 0.231W^C + 0.25W^B + 0.398W^A \ .$$

The fallout wind shear is then computed by the fallout wind speed times the sine of the absolute value of the difference of the wind directions at level D and E, all divided by 20.

Next, points are generated on a two degree latitude/longitude grid ranging from, latitude L = from 24 to 50 degrees and, longitude λ = from 65 to 125 degrees. For each point, generated grid coordinates are calculated by

$$II = 24 + 31.18(\cos(\lambda - \tfrac{\pi}{2})) \tan(\tfrac{\pi}{2} - \tfrac{L}{2})$$

$$JJ = 26 - 31.8(\sin(\lambda - \tfrac{\pi}{2})) \tan(\tfrac{\pi}{2} - \tfrac{L}{2}) \ .$$

The values of II and JJ are truncated to integers and the inverse of the above transformation used to get the latitude and longitude of the wind grid point. From this the distance from the wind grid point to the monitor point is calculated. The process is repeated to calculate the distances of the other three wind grid points surrounding the monitor point from the monitor points. If $D_A \ldots D_D$ are the distances and $W_A \ldots W_D$ are the winds at the four wind grid points, then the wind at the monitor point, W_M, is estimated by

$$W_M = \frac{W_A/D_A + W_B/D_B + W_C/D_C + W_D/D_D}{1/D_A + 1/D_B + 1/D_C + 1/D_D} \ .$$

The averaging is performed on north-south and east-west components of the wind. This averaging method is the same used in the SIDAC damage assessment system. The latitude/longitude of the two degree grid points, the wind speed, wind direction and wind shear are then written on the output file. The process is repeated until all two degree grid points have been processed.

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Abstract

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